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DIELECTRIC LOSSES IN INSULATING MATERIALS.*

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INSULATING materials and insulated structures comprise such a tremendous variety in kinds, qualities, and applications that no one test has ever been found which will give even the major part of the information desired in connection with them. Furthermore, in the construction of dynamo electric machinery and apparatus, the value of exact information in regard to insulation has received a rather tardy recognition from designing engineers in general, but, fortunately, the importance of this subject is now more fully recognized. Of the four general classes of materials entering into the construction of dynamo electric machinery and apparatus, insulation is by far the most difficult to evaluate. The other three classes—namely, conducting material, magnetic material, and structural material—have all received more attention in the past, and they are also more readily evaluated with regard to those qualities desirable in the construction of electrical apparatus. The conductivity of copper, the most used conducting material, for example, can be measured with perfect definiteness to a small fraction of one per cent. The mechanical characteristics of this material are some-

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what more difficult of measurement, but, for all practical purposes, can be evaluated to a sufficient degree to allow perfectly definite application to be made. Permeability, hysteresis loss, and eddy current loss in magnetic material can be measured with a fair degree of accuracy, and the mechanical characteristics of such material can be determined with the same degree of precision as those of any other material. The determination of the essential characteristics of structural material used for structural purposes only, in electrical machinery and apparatus, presents a problem common to the determination of such qualities in all structural material. These three classes of material—namely, conducting, magnetic, and structural—are almost exclusively metals, and while there are many unsolved problems in connection with their use, and while a high degree of accuracy in the determination of all of their known qualities is not possible, yet there is far less uncertainty in these determinations than in the measurement of the characteristics of insulating material.

Insulating materials, as is well known, comprise an enormous variety of kinds, compositions, physical characteristics, and qualities. Gases, liquids, and solids are used for different purposes, and the chemical composition runs the whole gamut, from simple oxides, for example, to the most complex hydrocarbons and even more complex mixtures of many substances. In most instances the various characteristics of insulating materials available for a given application are such that the enhancement of any particular quality may require the sacrifice of another desirable quality. For example, increasing the dielectric strength of an insulating varnish usually results in increased brittleness. Increasing the fluidity of transformer oil usually results in decreasing its flashing-point. Increasing the fire-resisting qualities of most insulating structures decreases their mechanical strength and insulating value. It will be seen, therefore, that the study of insulation is an extremely complicated and far-reaching study, beset with many difficulties. Even the mechanical characteristics of insulation are more difficult to evaluate than the same characteristics of the other materials entering into the construction of electrical machinery. Each characteristic of insulating material becomes a special study in itself, and the variation of such a characteristic in different varieties of materials may be enormous. Contrast, for example, the heat resistance of electrical porcelain and of transformer oil.

In the early days of the exploitation of electrical apparatus the magneto was the main dependence of dynamo builders for determining whether or not the insulation was satisfactory. Insulation resistance was sometimes measured with an ordinary galvanometer and a few cells of battery. A little over 25 years ago the idea of making breakdown tests by applying actual potentials to the insulating structures began to be considered by the manufacturers of dynamo electric machinery. A fairly rapid development of this test, now known as the dielectric strength test, resulted, and it is now the main dependence of manufacturers for the evaluation of insulation and insulating structures.

The early use of this same test resulted in very rapid development and betterment in insulating materials and in the insulation of electrical machinery. In this early work tests of a few hundred volts were used for a given service voltage, where now the standard may be ten times as much, with far fewer breakdowns. There was no information available as to what constituted a proper test, and in many cases if apparatus for use on 500- or 1000-volt circuits stood 50 per cent. more it was considered satisfactory. At the period in which your speaker became familiar with this class of work we had no high-tension transmission lines, no voltages available for such testing higher than perhaps two or three thousand, there was no literature whatever available on the subject, and there was no coöperation along these lines between engineers in the various manufacturing companies. It became necessary, therefore, to develop for ourselves the whole art of dielectric testing, including the apparatus necessary for making such tests. From the beginning of a *high-voltage* testing set capable of giving a maximum of 6000 volts by small steps with about one K.V.A. capacity, we now have testing sets capable of giving 500,000 to 1,000,000 volts with a K.V.A. capacity of 500 or more. Ten thousand-, 30,000-, and 50,000-volt testing sets rapidly followed the original 6000-volt set, and with these facilities thousands of tests were made on all kinds of materials and structures. Without going further into the history of this particular development, it is sufficient to say that dielectric strength tests have finally emerged from their chaotic state to a point where they have been standardized by the American Institute of Electrical Engineers and a certain amount of international standardization as to values of test, methods of making them, etc., has been accomplished.

The measurement of insulation resistance has retained a place in insulation testing and is of very considerable value in determining the condition of the material or apparatus with regard to moisture, dirt, curing, etc. The mechanical and other similar characteristics of insulating materials have been studied, but, on account of the enormous variety of materials used referred to, no satisfactory universal test seems possible.

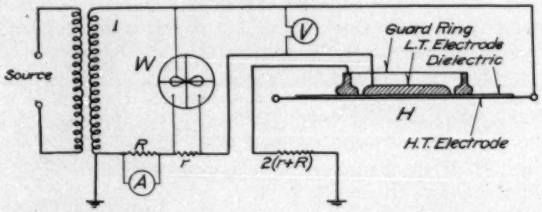
In spite of the standardization of the dielectric strength test for evaluating insulation, and its general adoption and national and even international standardization, it leaves much to be desired. The ultimate value of an insulation or an insulated structure cannot be measured by this method without its destruction. The fact that an armature, for example, stands a test of 10,000 volts gives no indication whatever as to where the structure may break down, and gives no indication of the condition of the insulation except that at the moment of the test it was capable of withstanding this applied electrical pressure. This deficiency in the dielectric strength test has been recognized by workers in this field for many years, and many attempts have been made to use other characteristics of insulation in the determination of its value for the purposes desired. It has long been known that when subjected to an alternating potential, a loss of energy takes place in insulation. While this loss is probably of a much more complicated nature than the hysteresis loss in steel and also much more difficult of measurement, such measurement may be made to serve a useful purpose. Numerous attempts have been made to use this characteristic in the evaluation of insulating materials for general use. A paper on this subject was presented before the annual meeting of the American Institute of Electrical Engineers in 1902 by your speaker, this paper being based on data obtained in several series of tests carried out with the able assistance of Messrs. Miles Walker and Percy H. Thomas. Among the tests described in this paper were several series of loss measurements on materials and on completed apparatus. These losses were obtained by means of a quadrant electrometer adapted for use as a wattmeter. In connection with this paper, another paper by Mr. Miles Walker gave a detailed description of the wattmeter used and the theory involved in its construction and calibration. This paper was followed by a classic paper by Mr. Rayner, of the National Physical Laboratory, before the British Institution of Electrical Engineers,

in 1912, Mr. Rayner's measurements also being made with a quadrant electrometer wattmeter. Other workers, notably Messrs. Minton, Shanklin, Thomas, Butman, and others, have given us very valuable contributions to this subject by the use of the cathode ray wattmeter, the electro-dynamometer wattmeter, and the Wien bridge.

All measurements of this class are fraught with many difficulties, regardless of the method and apparatus used. These difficulties may perhaps be appreciated when it is stated that not infrequently measurements must be made of a total value of less than ten watts at voltages of 25,000, 50,000, or even 100,000, and at a power factor sometimes less than five per cent.

During the last five years we have been carrying on practically continuous work on this subject, using a variety of methods, but

FIG. 1.



we have at last adopted the quadrant electrometer wattmeter as the most convenient and satisfactory instrument which we have been able to devise up to date. An instrument of this kind has been constructed which has given very satisfactory results, and upwards of 1000 curves involving variation in voltage, variation in temperature, variation in treatment of materials, etc., have been taken during the last year or two. A considerable variety of insulating materials has been studied in a preliminary way, and measurements have also been made on completed apparatus, such as transformers, generators, condenser bushings, etc.

It is my purpose to give you more or less in detail the construction and calibration of the instruments used, together with some of the characteristic results which have been obtained by their use, in order that other workers may benefit by our experience and go forward with this work.

For these measurements it is necessary to have, in addition to the wattmeter, suitable means of measuring voltages in the testing circuit up to the maximum voltage to be used on the test sample, and also means of measuring the current in this high-tension circuit. The following description, therefore, applies to the various instruments involved.

For this particular work an electrostatic voltmeter designed by Prof. H. B. Smith, of the Worcester Polytechnic Institute, was used. An electrostatic ammeter was adapted from a Kelvin multicellular static voltmeter. In the testing of sheet material it was also necessary to devise suitable electrodes for holding the specimens of sheet insulation so that a uniform field would be produced in that part under measurement. The majority of the tests have been made with materials under oil, as we were primarily interested in the use of these materials under oil, particularly in connection with their application to high-voltage transformers. In many cases measurement in air is difficult, if not impossible, on account of the formation of corona at the higher voltages, which very largely vitiates the results.

Fig. 1 gives the diagram of connections of the apparatus as used for these tests—T being the testing transformer; A the Kelvin multicellular voltmeter used as an ammeter, with its resistance, R; W the wattmeter, with its resistance, r; V the static voltmeter; and H the sample holder.

WATTMETER.

The wattmeter is a Kelvin quadrant electrometer adapted for use as a wattmeter, and is simply a refinement and enlargement of the instrument used 15 years ago for the same purpose. The cylindrical parts of the quadrants are of cast iron cast in one piece and turned to 16 inches internal diameter and then cut into four pieces. These quadrants are seven and one-half inches high, and the top and bottom parts are made of one-eighth-inch brass plate. The hole at the top through which the needle suspension passes is seven inches in diameter. All corners are very carefully rounded so as to reduce any tendency for brush discharge. The quadrants are mounted so that the distance between them may be varied from one-quarter inch to thirteen-sixteenths inch. With one-quarter-inch setting it was found entirely feasible to use a voltage of 10,000 between the wattmeter quadrants, which

was considerably higher than was found necessary in the testing of specimens of insulation. The base is supported on specially-treated slate, with micarta washers for spacers between the slate and the quadrants. The slate was thoroughly vacuum dried and then given six coats of baked varnish to prevent moisture absorption. The slate rests on a 2-inch pine base, which raises the quadrants sufficiently so that the high-tension lead may be brought in at the bottom of the containing case.

The needle is made of 1/32-inch sheet aluminum, surrounded on the edge by one-quarter-inch aluminum rod to prevent corona

FIG. 2.

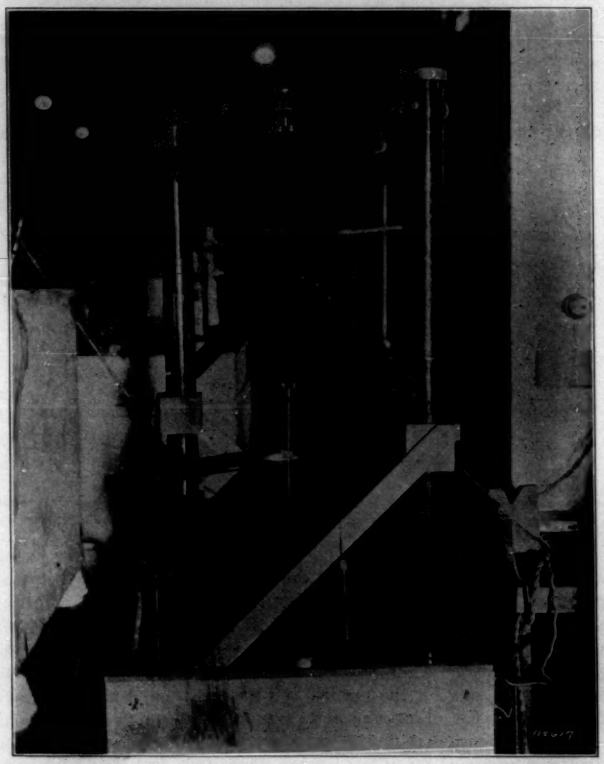
Wattmeter with one quadrant removed, showing interior.

disturbances. It is weighted at the centre to hold it in the centre position against the electrostatic forces which tend to pull it aside when a high potential is applied. With this construction, 70,000 volts may be applied between the needle and quadrants without pulling the needle aside from the centre position. A glass tube serves as an axis for the needle, and on this tube is mounted the mirror used for observing deflection.

The suspension is bifilar in type, consisting of two 0.01-inch diameter annealed phosphor bronze wires two feet long and one inch apart. This suspension is hung from a solid framework constructed of micarta tubes and treated maple. The suspension has been quite satisfactory, holding its zero position very well.

The whole instrument, excepting the suspension, is immersed in a tub of "HF" transformer oil. This serves to insulate the

FIG. 3.



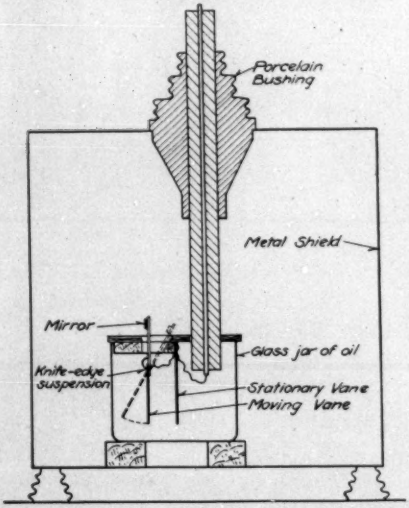
Wattmeter assembled, showing oil container, needle support, and bifilar suspension.

various parts as well as to damp the motion of the needle. The containing tub is made from an ordinary fibre wash-tub thor-

oughly dried and varnished. The instrument is placed on a rigid table of heavy maple thoroughly treated to prevent the absorption of moisture. The whole is completely surrounded by a shield of galvanized sheet iron to prevent errors which might otherwise be caused by stray electrostatic fields.

The high-tension lead is brought through the casing at the base of the instrument through a heavy porcelain bushing and passes to a heavy stud projecting through the bottom of the tub.

FIG. 4.

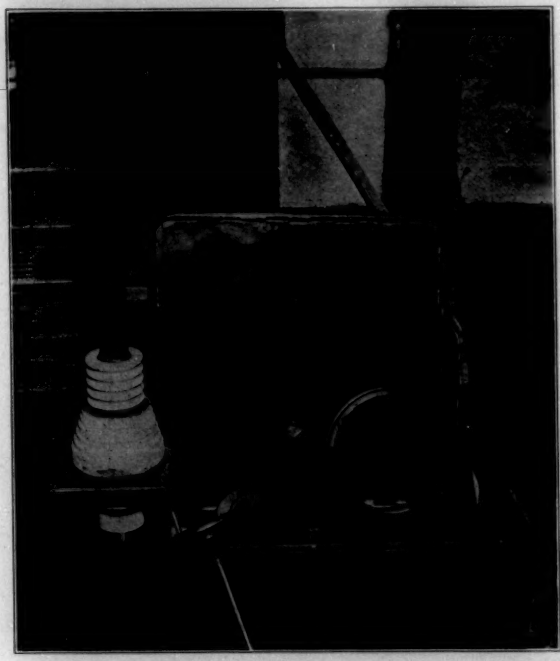


Electrostatic voltmeter.

On top of the stud is a mercury cup used for making contact with the needle. Metal guard disks are used on the stud above and below the bottom of the containing tub to eliminate corona at these points. The low-tension leads from the quadrants are brought out of the oil near the edges of the tub and pass through the side of the upper shield through suitable porcelain bushings. The instrument is levelled by suitable levelling screws applied to the supporting table.

The wattmeter resistance consists of two 50,000-ohm Weston resistances, each having a current capacity of 0.05 ampères. For larger currents a ribbon resistance specially manufactured by the Paul Instrument Company is used. Very careful check tests

FIG. 5.



Testing electrodes shown in containing tank with outlet terminal.

indicate that these resistances are practically non-inductive and have negligible capacity.

VOLTMETER.

The voltmeter used is shown diagrammatically in Fig. 4, and consists of a stationary vane, three inches by five inches, made of brass, with a moving vane of aluminum, three inches by three

inches. The moving element is supported on knife-edges and carries a mirror. The vanes are supported by blocks of treated maple, which are held in a glass jar of "HF" transformer oil. The whole is placed in a metal box to protect the meter from stray electrostatic fields. This box also serves as the low-tension (or grounded) terminal. The high-tension lead is brought in at the top through a suitable high-voltage porcelain bushing which

FIG. 6.

Assembled testing electrodes in tank, showing arrangement for securing pressure on test sample.

extends down into the oil, leaving no live parts exposed inside the case. The voltmeter box is supported on porcelain insulators, this arrangement allowing the metal box to be connected to the low-tension side of the load under test, which may be as much as 2000 volts above ground potential. Both the voltmeter and wattmeter are read by means of telescopes and illuminated scales six feet distant from the mirrors. The wattmeter scale is horizontal, 30 inches long, and the voltmeter scale, vertical, 50 inches long.

AMMETER.

The ammeter, as before indicated, consists of a multicellular electrostatic voltmeter with an adjustable shunt so that different values of resistance can readily be inserted without opening the circuit.

ELECTRODES AND OIL TANKS.

The construction of the electrodes was shown diagrammatically in Fig. 1. As will be seen in this sketch, the lower electrode

FIG. 7.

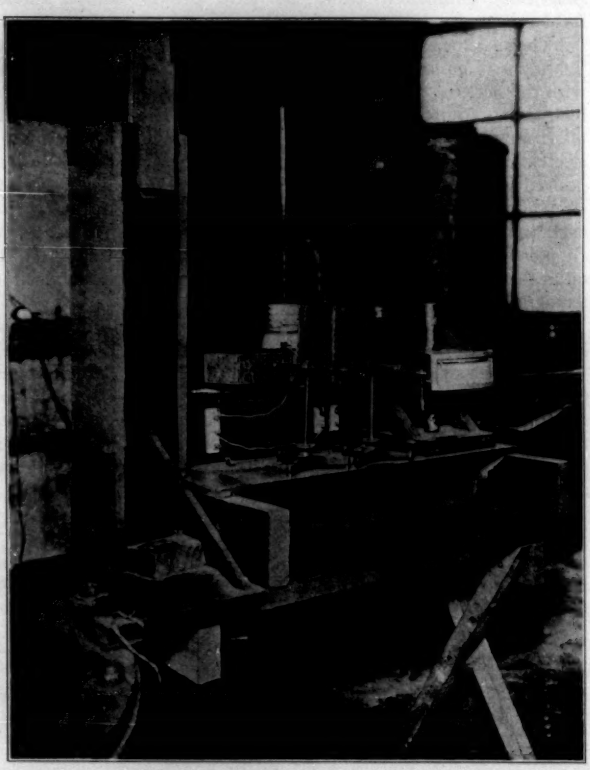
General view of testing apparatus.

consists of a thin sheet of steel with brass tubing completely surrounding this sheet to form a round edge, this being supported on suitable insulators in the containing tank and serving as the high potential or ungrounded electrode. The low potential or grounded electrode consists of a heavy circular casting surrounded by a carefully-finished guard ring, this serving to prevent stray fields and to keep the field uniform in that portion of the material under test.

The diameter of the low-tension electrode is 14.05 inches and

the inside diameter of the guard ring 14.3 inches, leaving a space of 1/8 inch between the electrode and guard ring. The contact

FIG. 8.



Observation desk, showing telescopes and static ammeter, with oil tank, test sample tank, and instruments in background.

surface of the low-tension electrode is 1000 square centimetres and the contact surface of the guard ring approximately 500

square centimetres. A resistance is inserted in the connection of the guard ring to ground such that the potentials of the ring and the low-tension electrode are the same, and therefore corona is practically eliminated from the part of the sample under measurement.

The specimen tank has a capacity sufficient to contain approximately 125 gallons of oil, and is connected to a storage tank, with the necessary pump to transfer the oil to or from the specimen tank. Approximately ten minutes are required to pump the oil from one tank to the other. In the storage tank are placed electric heaters with sufficient capacity for heating the oil to any desired temperature up to 130° C. Provision was also made for circulating the oil from the storage tank to the specimen tank and back and for keeping it at any desired level in the specimen tank. By means of the heaters and this arrangement for circulation the oil in the specimen tank can be adjusted to and held at any desired temperature during the test.

By means of a lever arm and weights, provision is made for applying any desired pressure up to ten pounds per square inch (0.7 Kg. per sq. cm.) on the specimen under test It was found that this pressure, applied before the admission of the oil to the specimen tank, satisfactorily kept the oil from the specimen under test. As most of the tests desired were on oil-soaked material, a certain amount of admission of oil, however, was not considered detrimental.

THEORY OF WATTMETER.

A. Fundamental Equation.

The fundamental equation for the quadrant electrometer, as stated and proved by Clerk Maxwell,[1] is:

$$T = K_1(AB)\left(C - \frac{A+B}{2}\right)$$

where

T = Torque on needle.
K_1 = Constant of the instrument.
A, B = Absolute potentials of the two pairs of quadrants.
C = Absolute potential of the needle.

The deflection of the instrument is seen to be proportional to the product of two voltages: the voltage between the pairs of

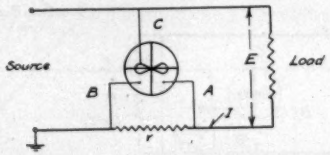
[1] Treatise on Electricity and Magnetism, vol. i, sec. 219.

quadrants, and the voltage between the needle and the mid-potential of the quadrants. When used on alternating current the phase relations of these two voltages is also a factor in determining the deflection, since two voltages which are 90 degrees apart can produce no torque in an electrostatic instrument of this kind.

B. Connection of Electrometer as Wattmeter.

Fig. 9 gives the diagram of the connections necessary for the use of an electrometer as a wattmeter, as used in these experiments. A, B, C are the potentials of the respective parts of the electrometer shown in the figure. E is the voltage across the load, and I the current. r is a non-inductive resistance, called the wattmeter resistance or potential divider, used to produce a difference of potential across the quadrants which is proportional to and in phase with the current I.

FIG. 9.



"C." Proof that Wattmeter Indicates Watts (100 per cent. P. F.).

Assuming the deflection (d) is proportional to the torque on the needle, which is true for the small deflections used, we have, from Maxwell's equation:

$$d = K_2(A-B)\left(C-\frac{A+B}{2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Here K_2 is a new constant.

If the load is a resistance only, the drop across the quadrants ($Ir = A-B$) is in phase with E, the voltage across the load. Now as B is earthed, its potential is zero; A, therefore, has a potential of Ir volts, and C of $(Ir+E)$ volts. The above formula becomes:

$$d = K_2(Ir)\left(Ir+E-\frac{Ir}{2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$= K_2r(EI+\frac{I^2r}{2}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Thus it is seen that the deflection is proportional to the sum of the watts consumed by the load plus half the I^2r loss of the wattmeter resistance. Should B be at some potential (say x) above

earth, and not zero, as in the figure, the discussion would not be changed, for then we would have:

$$d = K_2(Ir + x - x)\left(E + Ir + x - \frac{Ir + 2x}{2}\right) \quad \ldots\ldots(4)$$

which reduces to the same as (3):

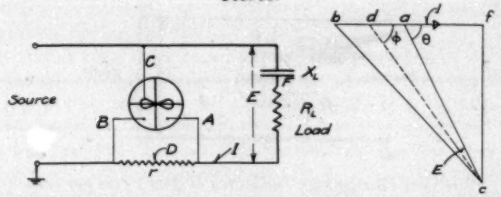
$$d = K_2 r\left(EI + \frac{I^2 r}{2}\right) \quad \ldots\ldots(5)$$

The foregoing discussion holds for loads having a power factor of unity. A proof for any power factor is as follows:

D. Proof of Wattmeter On Any Power Factor.

Fig. 10 gives a sketch of the circuit ordinarily met with in insulation testing, together with the vector diagram. R_1 and

FIG. 10.



X_1 represent the theoretical resistance and capacity of the insulation load, which has a power factor of cos θ. E is the potential drop across the load, and I the current. r is the wattmeter resistance, described above. The other letters, A, B, C, D, and F, refer to the potentials of those parts of the circuit which they represent, and correspond to the small letters a, b, c, d, and f in the vector diagram. ac is the voltage across the load, bc the voltage of the source, ba the voltage across quadrants, and cd the voltage from the needle to the middle point of the quadrant voltage. From Maxwell's fundamental equation, the deflection is proportional to the product of the voltage between quadrants (ab) and the voltage from the needle to the middle point of the quadrants (cd), or

$$\text{Deflection} = K_2 \times \overline{ab} \times \overline{cd} \quad \ldots\ldots(6)$$

$\overline{ab}$ and $\overline{cd}$ being vector quantities.

From the vector diagram in Fig. 10 this becomes, in scalar quantities:

$$\begin{aligned}\text{Deflection} &= K_2 \times ab \times cd \cos\phi \\ &= K_2 \times ab \times (ac\cos\theta + da) \\ &= K_2 Ir\left(E\cos\theta + \frac{Ir}{2}\right) \\ &= K_2 r\left(EI\cos\theta + \frac{I^2 r}{2}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)\end{aligned}$$

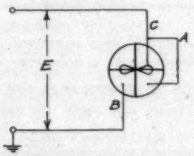
Thus it is seen that the wattmeter records watts for a condenser load (such as is common when insulating materials are tested). The proof for a reactance load is similar and will not be given here.

CALIBRATION OF INSTRUMENTS.

Wattmeter.

The constant of the electrometer wattmeter has been determined in several ways, each method checking within two or three

FIG. 11.



per cent. The usual method has been to connect the instrument as a voltmeter, as shown in Fig. 11. Applying the fundamental equation, the constant is found from the formula

$$K_2 = \frac{2d}{E^2}$$

where

K_2 = constant.
d = deflection.
E = voltage.

The instrument has been checked frequently and the variation of the constant found to be very small, the maximum variation during the considerably more than twelve months' use being not over two and one-half to three per cent. The constant for the

instrument is practically uniform over the entire scale length, the following data being a fair representative of the usual test:

Volts	Deflection, cm.	K.
1520	.46	3.98×10^{-7}
3140	2.01	4.07×10^{-7}
4790	4.70	4.10×10^{-7}
6440	8.40	4.05×10^{-7}
8120	13.32	4.04×10^{-7}
9720	19.05	4.03×10^{-7}
	Average	4.04×10^{-7}

The most reliable check on the wattmeter constant is made by measuring actual energy of known amount. The following table gives a summary of some tests made with known load:

Frequency	Calculated from load constants		Calculated from Wattmeter deflection. K.
	Total watts	P. F. of Load	
25	126.8	1.00	4.03×10^{-7}
25	88.2	.31	4.13×10^{-7}
25	140.8	.15	4.13×10^{-7}
60	124.	1.00	4.00×10^{-7}
60	132.2	.14	4.12×10^{-7}
60	126.	.065	4.13×10^{-7}
25	Calibration as a voltmeter		4.13×10^{-7}
60	Calibration as a voltmeter		4.12×10^{-7}

From the above tests it is seen that the wattmeter gives readings consistent within three per cent. on 60 and 25 cycles and on power factors from 6½ to 100 per cent. Lack of suitable condensers and resistances made it impossible to make any check tests with known loads below 6½ per cent. power factor. With the above tests checking so closely, however, it is safe to assume that the wattmeter is accurate on lower power factors within the limit of possible errors of reading the instrument and measuring the current, voltage, etc.

It should be noted here that the possible error is much greater with a low power factor, due to the fact that the watts registered by the meter is the sum of the loss in the load plus half the loss in the wattmeter resistance. So far a power factor of 1½ per cent. is the lowest that has been registered with this arrangement.

Possible Wattmeter Errors.

A very careful study was made of possible errors in the wattmeter, and it is believed that such errors have been very largely eliminated. It was found that the constant of the wattmeter was

more uniform with the quadrants set at the smaller distance of one-quarter inch from each other than for larger distances, and this setting was therefore used for all the measurements. It was found that the wattmeter would have a small deflection with the quadrants short-circuited and grounded and with a high voltage on the needle. This was due to dissymmetry in the location of the quadrants, and was corrected by adjusting the quadrants until zero deflection was obtained with high voltage on the needle and the quadrants connected together and to ground.

With voltages in excess of 70,000 the needle becomes unsteady, due to the electrostatic forces acting on it. Measurements were therefore confined to voltages below this value.

Mr. Rayner has noted an error due to the charging current to the needle. Most careful tests in the case of the instrument in question indicated that the amount of this error was negligible. As will be seen from the diagram of connections, any loss in the voltmeter will be measured by the wattmeter. Even at the highest voltages used it was found that these losses were so small that no perceptible difference could be detected in the readings of the wattmeter with the voltmeter connected or disconnected. The insulation resistance of the base of the wattmeter was considered a possible source of error, but measurements indicated this insulation resistance to be of such high value as to make any such error negligible.

The question has arisen as to whether there might be an error due to the inductance or capacity of the wattmeter resistance. Weston precision resistances are used, and tests were made in which no inductance or capacity could be detected. The voltage across these resistances is such that the effect of corona, or of leakage due to distributed capacity, is practically *nil*. The actual error due to a one-half per cent. capacitance in the wattmeter resistance can be shown to cause an error of but three per cent. in the wattmeter reading on an average sample of insulating material.

Some question may arise as to the accuracy of the meter on currents and voltages which have a wave shape other than sinusoidal. While care was used to supply as nearly as possible a sine-wave source of potential to the testing transformer, experiments show that in many cases the shape of the current wave through the dielectric is distorted in spite of any precautions that

may be taken. It should be noted here that the voltmeter and ammeter read the true effective values of volts and current regardless of wave shape. The mathematical proof of the wattmeter for wave shapes other than sinusoidal is more difficult, but such proof has been made. However, the consistency with which the measurements can be made of the energy losses in known loads having various power factors and producing distorted wave shapes is sufficient proof in itself that the wattmeter reads the true watts with wave shapes other than sinusoidal.

Calibration of Voltmeter.

The static repulsion type voltmeter, when first set up, was used with an equally divided scale. But, as the deflections are very nearly proportional to the square of the voltage, it has been found convenient to make a direct-reading scale. The meter holds its calibration extremely well, and there is apparently nothing to get out of order.

Calibrations have been made on 25 and 60 cycles, with an instrument transformer on the high-tension side of the testing transformer, and also by means of a voltmeter on the primary side of the testing transformer. In all tests the results agreed within a fraction of one per cent., and it has been thought unnecessary to calibrate further, except to check a few points on the scale occasionally. The meter has a good readable scale, from two to 57 kilovolts. The closeness to which it may be read is given in the table:

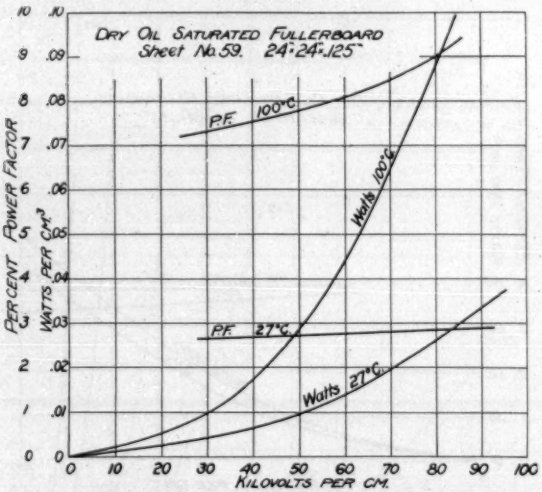
Scale reading	Smallest division which may be estimated
2 KV.	.1 KV.
5 KV.	.1 KV.
10 KV.	.05 KV.
25 KV.	.02 KV.
50 KV.	.01 KV.

RESULTS OF TESTS.

Data for many hundred watt loss curves have been taken with the apparatus described, an average of five points being taken for each curve. While the setting up, calibration, and operation of these devices require extreme care, when once adjusted measurements can be made quite rapidly and satisfactorily and, it is believed, with a degree of accuracy sufficient for all practical purposes. It was found comparatively easy for one operator to make all calculations and plot logarithmic curves of watt loss, power factor, and current against voltage for any given

sample in the time required for another operator to remove the sample from the tank and replace another, which ordinarily occupied about twelve minutes. In adjusting for temperature, considerable time is naturally consumed, and it is interesting to note that the point at which the temperature of a given sample had reached a uniform value throughout for any given temperature was determined by the measurement of insulation resistance. It

FIG. 12.

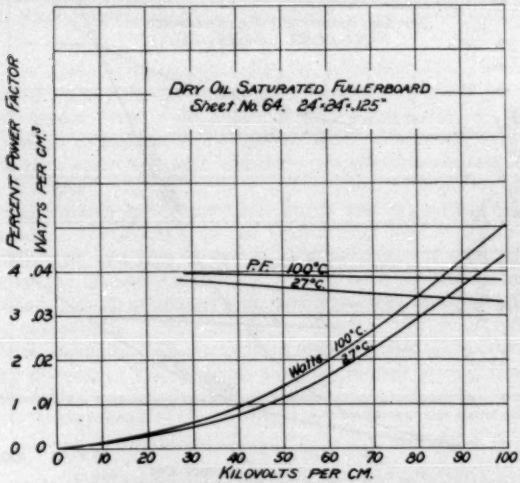

DRY OIL SATURATED FULLERBOARD
Sheet No. 59. 24·24·.125"
PERCENT POWER FACTOR
WATTS PER CM³
P.F. 100°C.
Watts 100°C.
P.F. 27°C.
Watts 27°C.
KILOVOLTS PER CM.
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10
0 .01 .02 .03 .04 .05 .06 .07 .08 .09 .10

This sheet was dried and saturated with oil by the vacuum pressure method. It then stood 10 days in air in the laboratory before being tested in oil

was considered that the temperature of the sample had reached a constant value when the insulation resistance became constant. The time required varied, of course, with the kind and bulk of the sample under test. Insulation-resistance readings were usually made on samples as well as loss and power factor readings, these insulation-resistance measurements being made with direct-current voltages up to 10,000.

The following curves give a number of specific examples of the results obtained by this investigation. These curves should not, however, be taken as representative of the various classes of materials, due to the fact that in practically all classes investigated different samples of the same material often show as much variation as different kinds of materials, and, as will be shown, the results are profoundly influenced by various kinds of treatment.

FIG. 13.



This sheet was tested in oil immediately after being dried and saturated with oil by the vacuum pressure method.

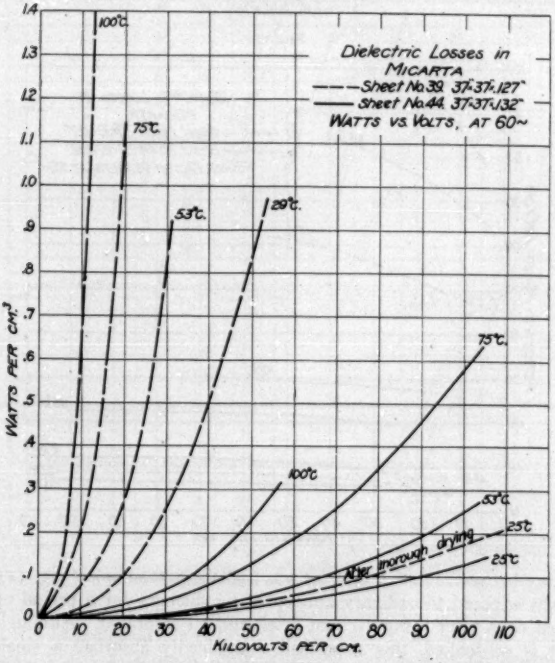
This study has been of very great value in various manufacturing processes in pointing out the kind and duration of treatment necessary to put various materials into the best condition for use, but in order to draw satisfactory conclusions from any sample or set of samples it is necessary to know something of their mode of preparation, previous treatment, etc. In general it may be said that the lower the losses and power factor and the higher the insulation resistance the better the quality of the insulation.

As a rule, low specific inductive capacity is desirable, but not for all uses.

SHEET MATERIAL, SUCH AS FULLER-BOARD, MICARTA, ETC.

One of the most commonly used materials for electrical insulation is known as fuller-board or press-board. This material is very largely used, especially in large, high-voltage transformers,

FIG. 14.

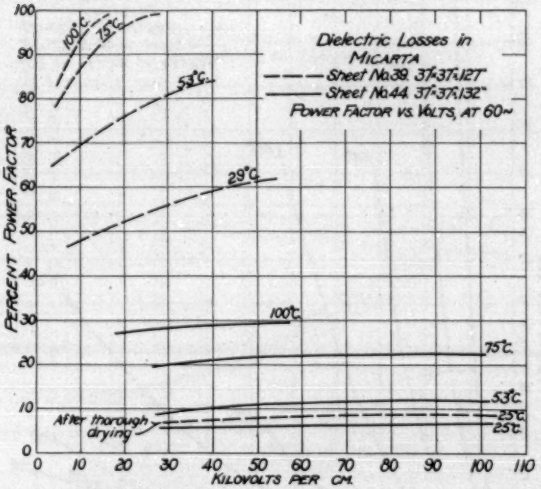


for the main insulation. In some cases this fuller-board is treated with a varnish or a drying oil, and in other cases it is merely thoroughly dried and impregnated with the oil in which the transformer is immersed.

Fig. 12 shows the relation between power factor and kilovolts per centimetre thickness, and also the relation between watts per cubic centimetre and kilovolts per centimetre thickness at two temperatures.

Fig. 13 gives a similar curve for a second sample of the same material, and it will be noted that there is a very wide difference in the values of the watts loss and power factor of the two samples, particularly at a temperature of 100° C. The only known differ-

FIG. 15.

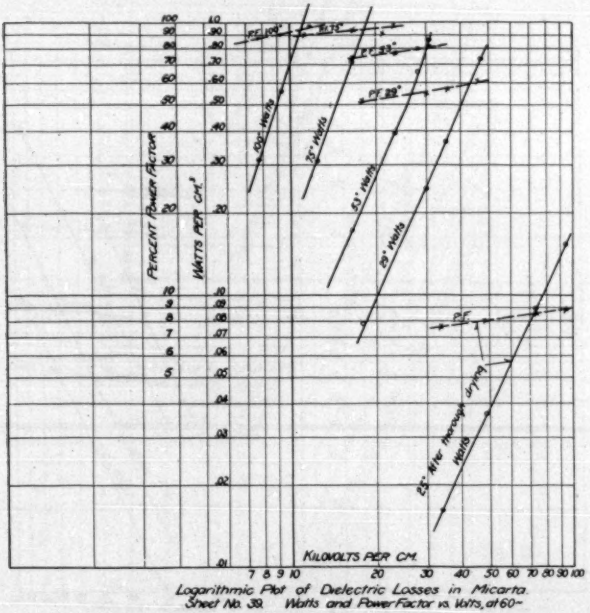


ence between the two samples was that the first sample (Fig. 12) was exposed to ordinary atmospheric influences for a period of ten days after being vacuum dried and oil saturated. Although it is oil-soaked, this sheet had undoubtedly absorbed a small amount of moisture which affected its insulation resistance at high temperatures, as well as its other characteristics. Dielectric tests made on these materials in the ordinary manner would show little or no difference in quality. Even the poorer results are considered

very satisfactory, as it will be seen that the losses are extremely small and the power factor relatively low.

Fig. 14 gives the relation of watts per cubic centimetre to kilovolts per centimetre on two samples of micarta sheet which were purposely taken in very different condition as regards their

FIG. 16.



Logarithmic Plot of Dielectric Losses in Micarta.
Sheet No. 38. Watts and Power Factor vs. Volts, at 60~

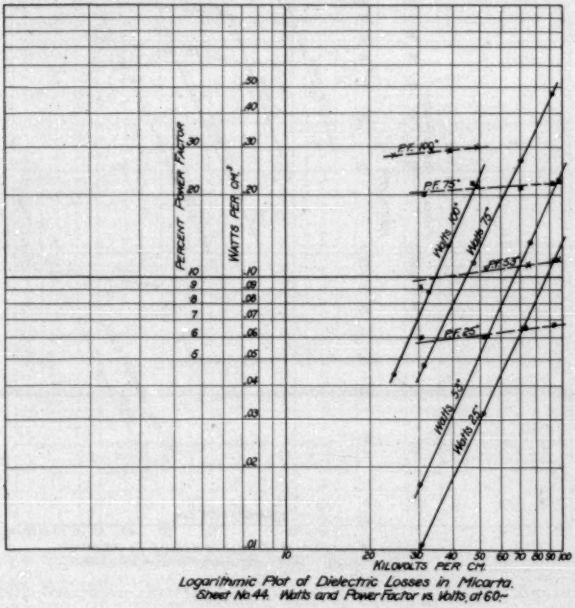
previous preparation. Sheet 39 was only partially processed, and it will be seen that the losses are excessive. The same sheet was again tested, after thoroughly drying, as indicated by the broken curve at the lower part of the figure, and a very decided improvement in the material is shown.

Fig. 15 shows the relation between power factor and kilovolts per centimetre for the same samples as shown in Fig. 14.

It will be seen that in the uncured condition the power factor of this material reaches almost 100 per cent. at the higher temperature. The power factor is considered relatively high even for the better samples, and, as has been shown in other tests, this can be greatly reduced by proper processing.

The same data given on Figs. 14 and 15 are repeated on

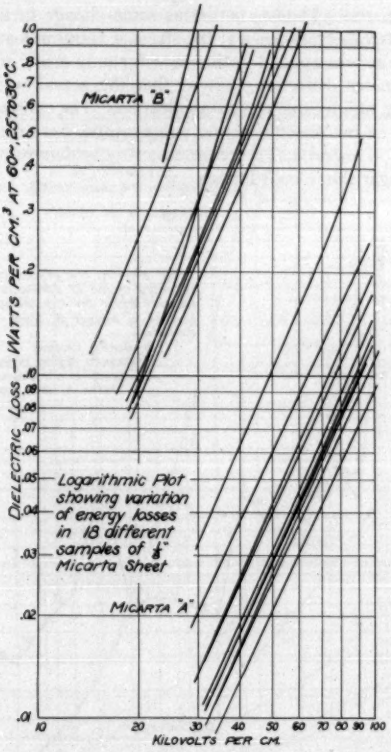
FIG. 17.



Logarithmic Plot of Dielectric Losses in Micarta. Sheet No. 44. Watts and Power Factor vs. Volts, at 60.—

Figs. 16 and 17, plotted to logarithmic scale, and in this case the actual observation points have been included. It will be noted particularly on these logarithmic scales that the slope of the watt voltage curve increases with temperature. The straight part of this curve may be expressed by the formula

FIG. 18.



$$W = KE^n$$

where

W = Watts
E = Kilovolts
K = A constant for a given temperature and frequency
n = An exponent indicating the slope of the curve on the logarithmic plot

The point where the watt loss curve departs from the straight line (Fig. 16—53° test) indicates some change in the material which foretells breakdown if the stress is continued at this value. The voltage was applied in this case for only a few seconds, and the wattmeter deflection showed that the actual watt loss was increasing rapidly due to this application. The subsequent measurements on this sheet at higher temperatures were made at lower voltages. This critical point is most readily determined by plotting to logarithmic coördinates.

FIG. 19.

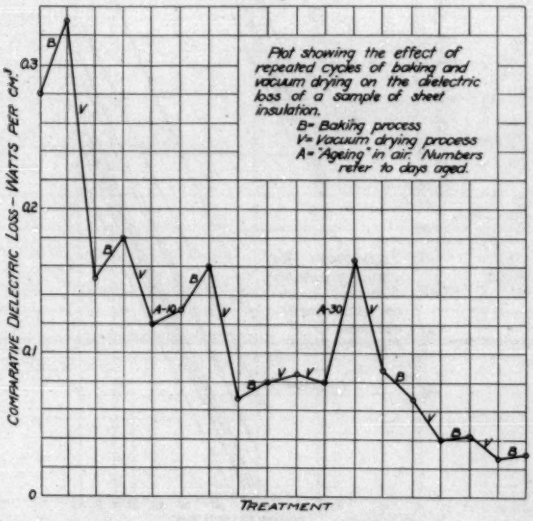
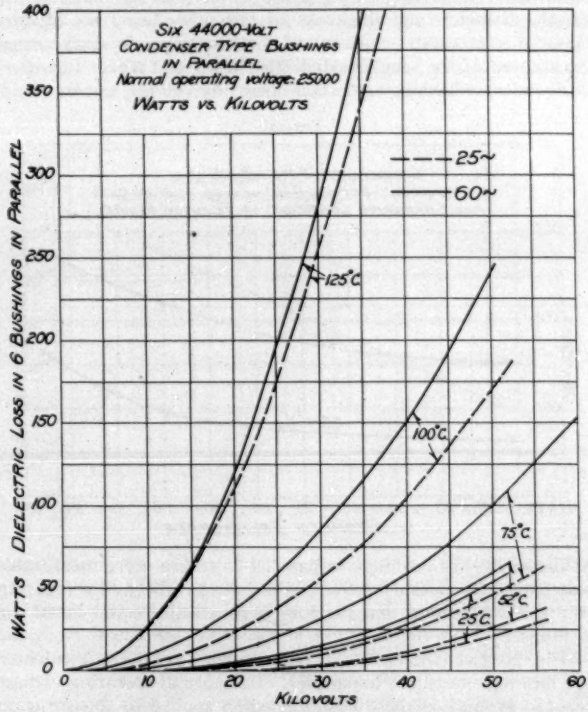

Plot showing the effect of repeated cycles of baking and vacuum drying on the dielectric loss of a sample of sheet insulation.
B= Baking process
V= Vacuum drying process
A= "Ageing" in air. Numbers refer to days aged.
COMPARATIVE DIELECTRIC LOSS - WATTS PER CM.³
0.3
0.2
0.1
0
A-10
A-30
TREATMENT

Fig. 18 gives the results of tests on a number of samples of micarta plotted to logarithmic scale. When plotted to this scale, the upward bend at the upper end of some of the curves indicates in those cases that the material was approaching very closely to its breakdown value.

Fig. 19 is extremely interesting as showing the variation in dielectric loss of sheet insulation when subjected to various treat-

ments. In a general way this plot can be taken as characteristic, particularly for sheet insulation treated or filled with varnish, and shows that such losses can be very greatly decreased by proper treatment. While insulation resistance measurements were not

FIG. 20.



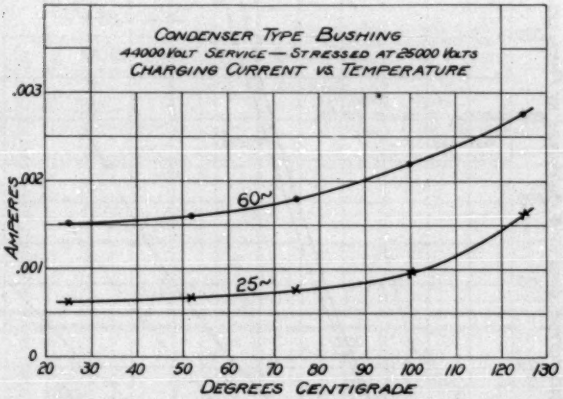
taken, it is probable that the effect of the treatment has been much greater numerically on the insulation resistance than it has been on the dielectric loss, particularly at high temperatures. Attention should be called to the fact, however, that at ordinary tem-

peratures the dielectric loss is a far better indication of the quality of the material than the insulation resistance.

CONDENSER BUSHINGS.

The condenser bushing consists, essentially, of concentric tubes of micarta, with intervening tubes of conducting material, the length, diameter, and thickness of the tubes being so adjusted that the electrostatic capacity of the successive layers is equal. On account of the very low dielectric losses and power factors of this condenser bushing at normal operating voltage, test was made

FIG. 21.



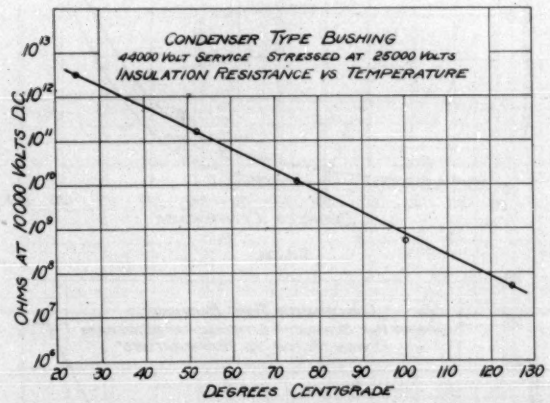
by measuring six bushings in parallel to secure more measurable quantities. By measuring five bushings in parallel and comparing results it was found that the loss is practically equal in all the bushings.

Fig. 20 gives the results of tests on six 44,000-volt condenser type bushings measured in parallel. The normal operating voltage stress to ground on these bushings when applied to apparatus on a 44,000 volt transmission system is approximately 25,000, and the maximum temperature which they will likely reach in service will not be over 75° C., due to conduction of heat from other parts of the apparatus. It will be seen, therefore, that even at 60 cycles

the watts per bushing in normal operation will be certainly not over 10 and at 25 cycles not over three or four watts. It is interesting to note that the watt loss at temperatures below 75° C. varies practically as the frequency. It should also be noted that the increase in loss is very rapid at 100° C. or higher.

Fig. 21 shows the relation between charging current and temperature at 25 and 60 cycles on the same set of bushings, and Fig. 22 shows the relation between insulation resistance and temperature. In Fig. 22 the insulation resistance was measured at 10,000 volts direct current, and insulation resistance is plotted to

FIG. 22.



logarithmic scale. The insulation resistance is 316 times as great at 25° C. as at 75° C.; 3160 times as great at 25° C. as at 100° C., and about 100,000 times as great at 25° C. as at 125° C. This change of insulation resistance is so great that the losses due to actual conduction are much greater than those due to the so-called hysteresis or dielectric losses. This explains the reason why the losses at both 60 and 25 cycles are so nearly the same at 125° C. At 75° C., or maximum possible operating temperature, the insulation resistance is 10,000 megohms.

Figs. 23 and 24 show the relation of dielectric loss to temperature and the relation of power factor to temperature for the

same set of bushings. Again, it will be seen by these curves that the critical losses begin to manifest themselves at temperatures between 80° C. and 90° C.

FIG. 23.

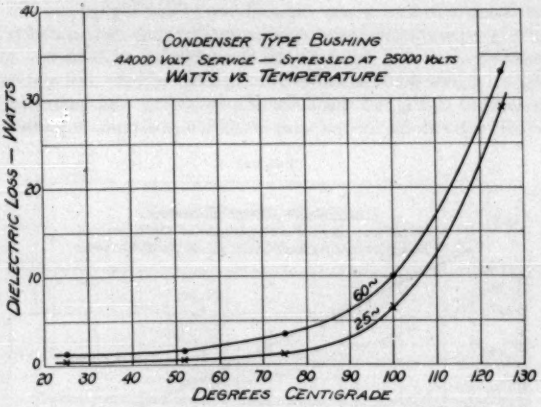


FIG. 24.

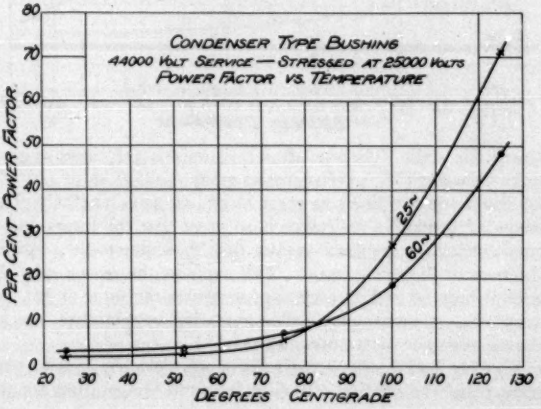
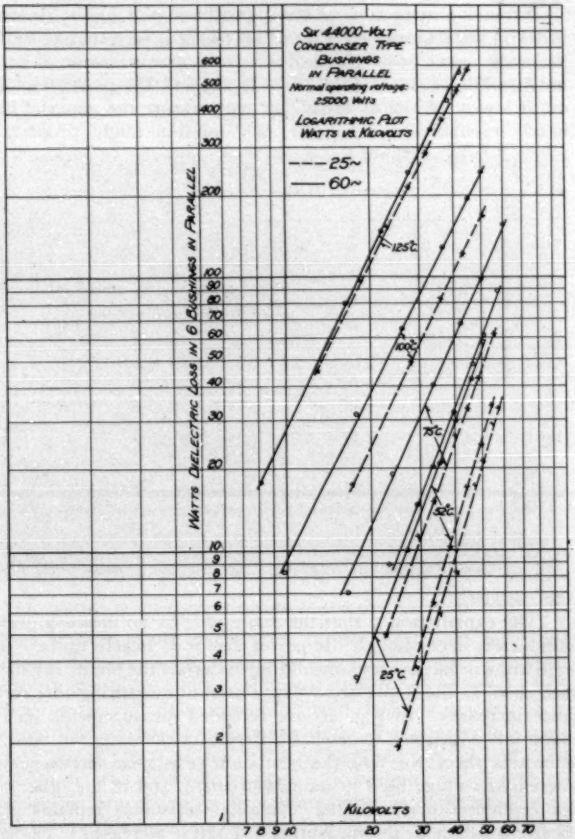


Fig. 25 is a logarithmic plot of the relation between dielectric loss and kilovolts applied to these same bushings, and the actual

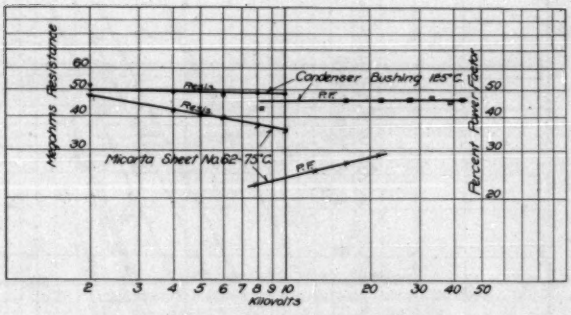
FIG. 25.



readings taken are plotted on these curves. It will be noted that the loss at 25 cycles is increased approximately 15 times by raising the temperature from 25° C. to 100° C. At 60 cycles the corresponding change is approximately six times.

From the inspection of the logarithmic plot of the dielectric losses in micarta sheet No. 39 (Fig. 16) it is seen that at 100° C. the watts curve has a slope of 2.8 and a power factor of nearly unity, while at 29° C. the slope is 2.4 and the power factor is much lower. Since at the higher temperature the material more nearly resembles a conductor, the question might properly be asked, "Why does not the slope of the watts curve approach two

FIG. 26.



as the power factor approaches unity with the increasing temperature, since the losses in conductors vary with the square of the voltage?"

The explanation is that the material is by no means a perfect conductor, even though the power factor is nearly unity. It is well known that in many insulating materials the ohmic resistance decreases as the impressed voltage used in measuring this resistance increases. In Fig. 26 are recorded measurements on two materials which are somewhat different in character; in one case (micarta sheet No. 62) the insulation resistance decreases with increased voltage used in its measurement, and in the other case (a condenser bushing) the insulation resistance remains practically constant as the measuring voltage is increased. The con-

denser bushing values are for a single bushing derived from the test on six bushings in parallel before referred to. In both cases the power factors are relatively high, this being a condition found at the higher temperatures at which both sets of measurements were made; and, furthermore, it will be seen that in the case of the condenser bushing the power factor remains practically constant with varying voltage, as well as the insulation resistance, while with the micarta sheet the power factor increases with in-

FIG. 26-A.

400 KVA., 6000-volt, 50-cycle synchronous condenser stator on insulating base ready for test.

creased voltage in about the same proportion as the insulation resistance decreases with increased voltage. This relation between insulation resistance and power factor, which, we believe, is here shown for the first time, appears to hold only for power factors of more than fifteen or twenty per cent. For materials having a lower power factor no such relation has been noticed. Micarta sheet No. 62 was chosen from one of the varieties which requires considerable processing in its manufacture, and the tests were made before this final processing. We have found it possible to carry the treatment of this material to a point where the insula-

FIG. 27.

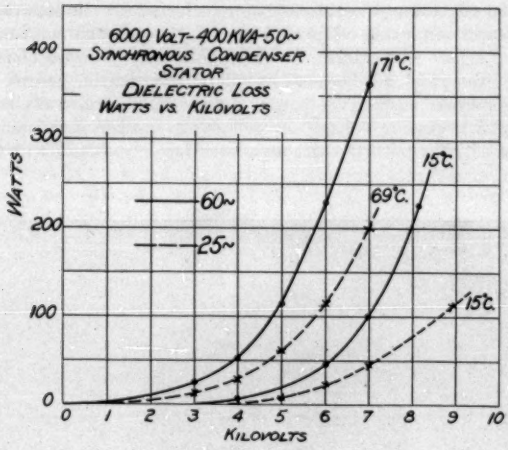
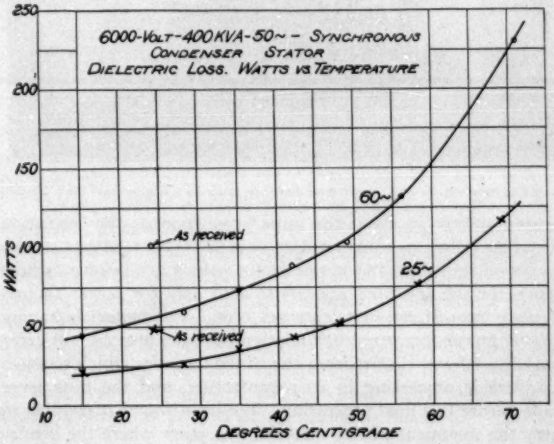

6000 VOLT-400 KVA-50~
SYNCHRONOUS CONDENSER
STATOR
DIELECTRIC LOSS
WATTS VS. KILOVOLTS
WATTS
KILOVOLTS
60~
25~
71°C.
69°C.
15°C.
15°C.
0
100
200
300
400
0 1 2 3 4 5 6 7 8 9 10

FIG. 28.


6000-VOLT-400 KVA-50~ - SYNCHRONOUS
CONDENSER STATOR
DIELECTRIC LOSS. WATTS VS TEMPERATURE
WATTS
DEGREES CENTIGRADE
60~
25~
As received
As received
0
50
100
150
200
250
10 20 30 40 50 60 70

tion resistance and the power factor will remain constant with varying voltage. Particular attention is called to the fact that the sheet material in this curve is not in proper condition with regard to processing, and the condenser bushing measurements are at a temperature which would never exist in practice.

SYNCHRONOUS CONDENSER STATOR.

A synchronous condenser stator of 400 KVA. capacity, 6000 volts, 50 cycles, shown in Fig. 26 A, was measured and the results are given in curves Figs. Nos. 27, 28, 29, 30, and 31. During the test the machine was supported on a crib of well seasoned wood, which gave a very high insulation resistance from the machine to ground. It was found necessary to heat the winding by passing current through it, and when a temperature of approximately 70° C. was reached the heating was discontinued and the measurements started. Measurements of loss and power factor were made at atmospheric temperature before heating, as shown on Figs. 28 and 30. The temperature was measured both by thermometers and by the variation in the resistance of the winding and temperatures recorded are the averages of the temperatures measured. These temperatures are probably correct within two to five degrees. Loss tests were made with all windings connected in parallel and with the stress applied between the winding and the iron core. Special attention is called to the fact that the actual losses during normal operation of the machine will be not over one-third of the losses measured with the normal operating voltage applied to the insulation, since in normal operation the terminal ends of the winding only are subjected to this higher stress.

Fig. 27 shows the relation between the watt loss in the insulation and the voltage applied at 25 and at 60 cycles. Fifty cycles, the normal frequency rating of the machine, was not convenient for the tests.

Fig. 28 shows the relation between watt loss and temperature; Fig. 29 the relation between charging current and temperature; Fig. 30 the relation between power factor and temperature; and Fig. 31 the relation between insulation resistance and temperature. At 6000 volts the measured loss is about 0.007 watt per cubic centimetre at 15° C., 60 cycles, and about 0.0315 watt per cubic centimetre at 71° C., 60 cycles, but, as above indicated, the average

FIG. 29.

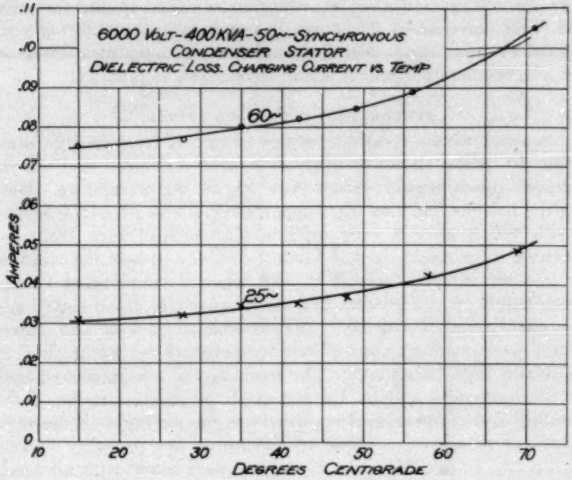

6000 VOLT-400 KVA-50~ SYNCHRONOUS
CONDENSER STATOR
DIELECTRIC LOSS. CHARGING CURRENT VS. TEMP
60~
25~
AMPERES
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
10
20
30
40
50
60
70
DEGREES CENTIGRADE

FIG. 30.

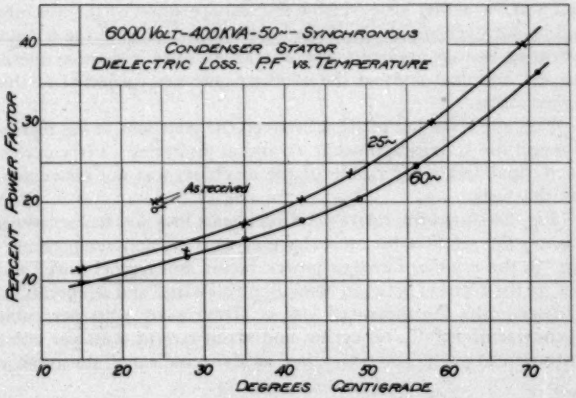

6000 VOLT-400 KVA-50~ SYNCHRONOUS
CONDENSER STATOR
DIELECTRIC LOSS. P.F VS. TEMPERATURE
25~
60~
As received
PERCENT POWER FACTOR
40
30
20
10
10
20
30
40
50
60
70
DEGREES CENTIGRADE

FIG. 31.

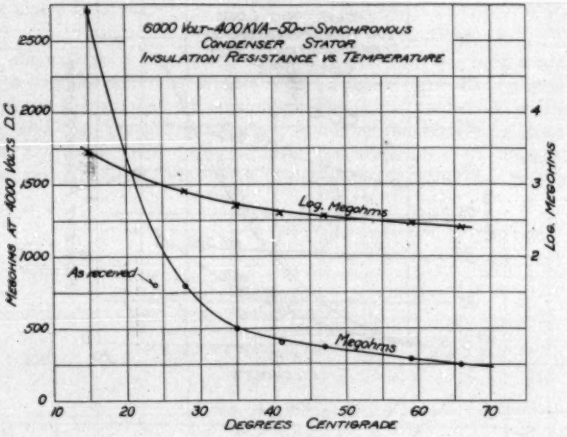

6000 Volt-400 KVA-50~ Synchronous
Condenser Stator
Insulation Resistance vs. Temperature
Megohms at 4000 Volts D.C.
Log. Megohms
As received
Megohms
Degrees Centigrade
0
500
1000
1500
2000
2500
2
3
4
10
20
30
40
50
60
70

FIG. 32.

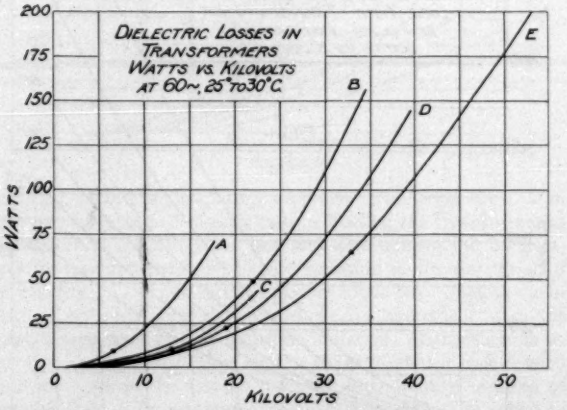

Dielectric Losses in
Transformers
Watts vs. Kilovolts
at 60~, 25° to 30° C.
Watts
Kilovolts
A
B
C
D
E
0
25
50
75
100
125
150
175
200
10
20
30
40
50

FIG. 33.

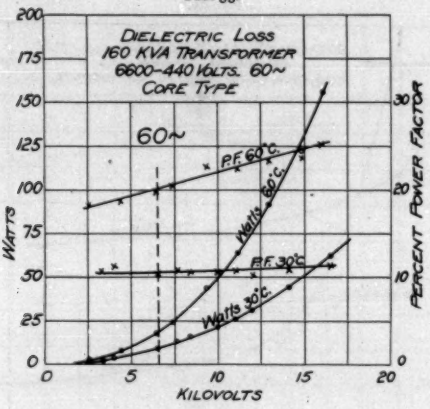
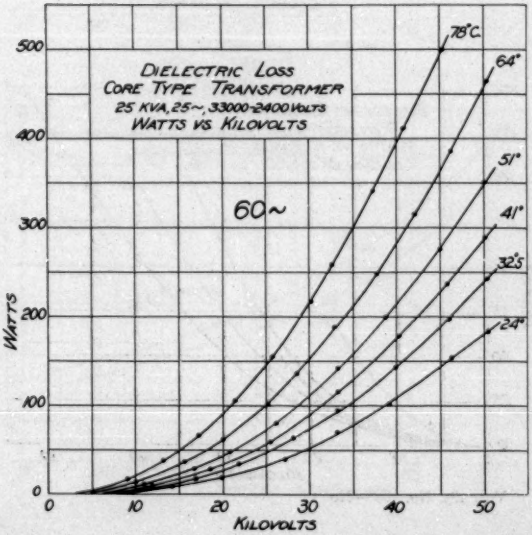

DIELECTRIC LOSS
160 KVA TRANSFORMER
6600-440 VOLTS. 60~
CORE TYPE
60~
P.F. 60°C.
WATTS 60°C.
P.F. 30°C.
WATTS 30°C.
WATTS
PERCENT POWER FACTOR
KILOVOLTS
0
25
50
75
100
125
150
175
200
5
10
15
20
30

FIG. 34.

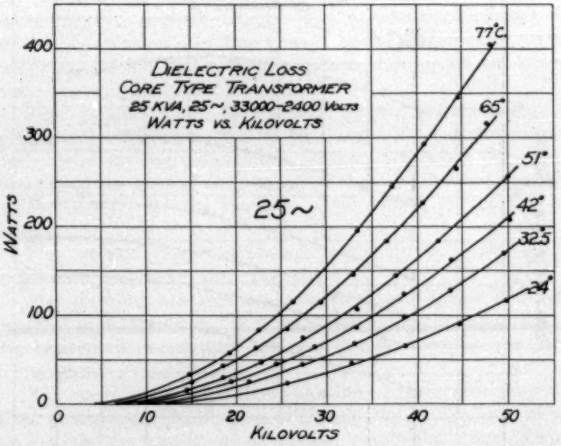

DIELECTRIC LOSS
CORE TYPE TRANSFORMER
25 KVA, 25~, 33000-2400 VOLTS
WATTS VS. KILOVOLTS
60~
78°C.
64°
51°
41°
32.5
24°
WATTS
KILOVOLTS
0
100
200
300
400
500
10
20
30
40
50

under actual operating conditions would be not over one-third of the above amounts.

TRANSFORMERS.

An extremely interesting set of measurements has been made on a number of transformers. In all cases the measurements were made from the high-tension winding to the low-tension winding and core connected together, or under the same conditions which prevail when dielectric tests are made on these devices. The transformers were, as in the case of the generator before

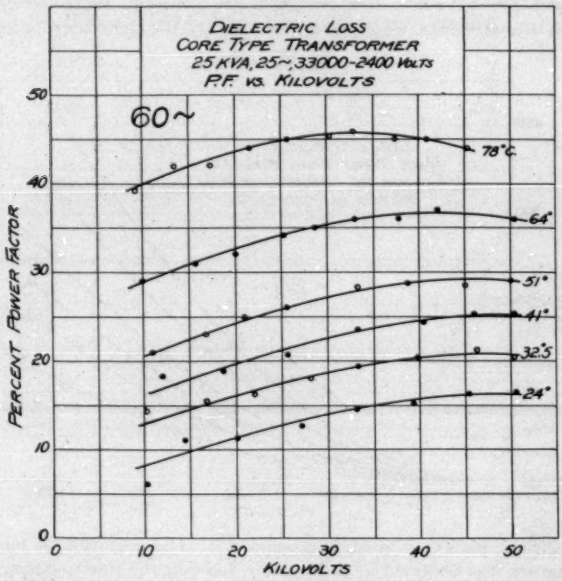
FIG. 35.



described, placed on insulating supports. The variation in temperature was obtained in each case by loading the transformer as under normal conditions of test and determining the temperatures by thermometers and by the variation in the resistance of the winding. Loss measurements were made only when the temperature by resistance showed practically agreement with the temperatures taken by thermometers in the oil. Dielectric tests on the oil were made from time to time to insure that it was in good condition. As in the case of the tests on individual samples of material, it is fully realized that these tests should be taken as

indicative of the type of variations which will be found under the conditions and not as giving precise values which may be applied to other devices of the same kind. Attention is also especially called to the fact that, as in the case of the synchronous condenser stator, the actual losses in operation will be only approximately one-third of the losses indicated on the curves at normal operating

FIG. 36.



voltage. These losses in service will vary with the particular connections used in operation and also with the condition of the insulation as indicated by the equation $W = KE^n$.

Fig. 32 gives the results of measurements at atmospheric temperature on five transformers, this curve showing the relation between watt loss and applied voltage. In each case the normal operating voltage of the transformer is indicated by the plotted

point on the curve. The capacities and voltages of these transformers, all of which are of the core type, are given in the following table:

Transformer.	KVA.	Volts, H.T.	Volts, L.T.	Frequency.
A	160	6,600	440	60
B	100	22,000	2,400	60
C	50	13,000	220	60
D	25	19,000	440	60
E	25	33,000	2,400	25

Fig. 33 gives a typical curve taken on transformer "A" (Fig. 32), showing the relation of watt loss to applied voltage and power factor to applied voltage. The vertical line indicates the normal high-tension operating voltage of the transformer. Particular attention is called to the increased slope of the power factor curve at the higher temperature.

Figs. 34 and 35 give the complete record of the readings of watt loss and applied voltage at 60 cycles and 25 cycles, respectively, with varying temperature. These curves are interesting as showing the general form taken by these curves and the relative consistency of the readings from which the curves are derived.

Figs. 36 and 37 give the power factor curves corresponding to the watt loss curves in Figs. 34 and 35.

Fig. 38 gives the relation between power factor and temperature of transformer "E" at 25 and 60 cycles, and Fig. 39 the relation between watt loss and temperature at the same frequencies.

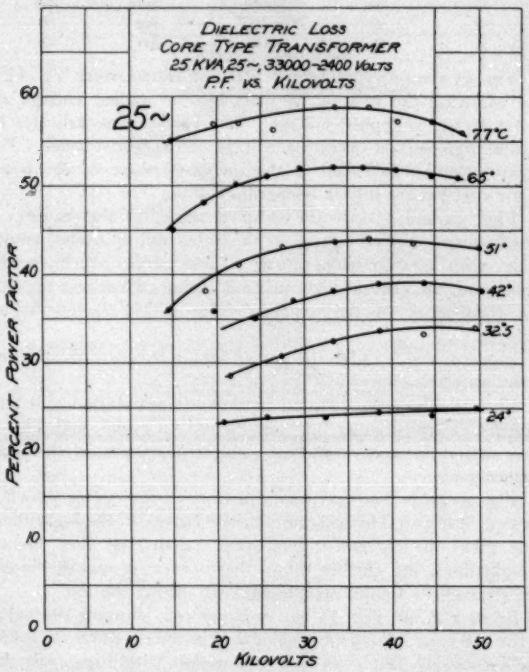
Fig. 40 gives the logarithmic plotting of the curves shown in Figs. 34 and 35. The plotting of these curves to the logarithmic scale gives the extremely interesting result that they become straight lines, and further shows that in no case was the insulation strained to a point near breakdown during the test.

From Fig. 40, Fig. 41 has been derived, showing the values of the constant K and the exponent n in the equation $W = KE^n$. The interesting fact to note in connection with Fig. 41 is that the watt loss increases more rapidly with voltage at low temperature than at high temperature.

As before stated, the work which has been described has given us much valuable information with regard to specific problems in our manufacturing processes, and it has also shown that the

dielectric loss test can be made a very valuable adjunct to the dielectric strength test and the insulation resistance test. It will probably never supersede the dielectric strength test as a control method in manufacturing operations, and it is doubtful whether it will ever be used as a criterion by the purchaser of electrical

FIG. 37.

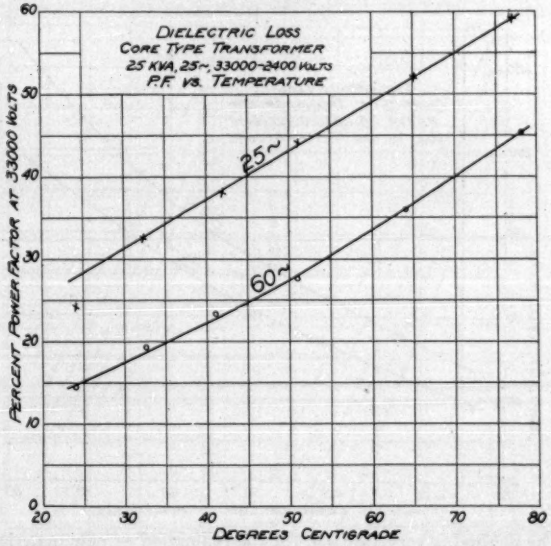


apparatus for the rejection or acceptance of the same. This method will without doubt be of more value to the manufacturer than to the user of electrical machinery.

Attention is again called to the fact that, while we have given the exact figures obtained in our measurement of losses, these

can hardly be taken as generally representative of the classes tested, but we believe that they do show the type of results and the forms of curves which may be expected from such measurements. It should also be remembered that, while the losses in some materials and sometimes in samples of the same class of materials show very wide variation, the actual total losses are very small as compared with the iron losses, copper losses, etc.,

FIG. 38.



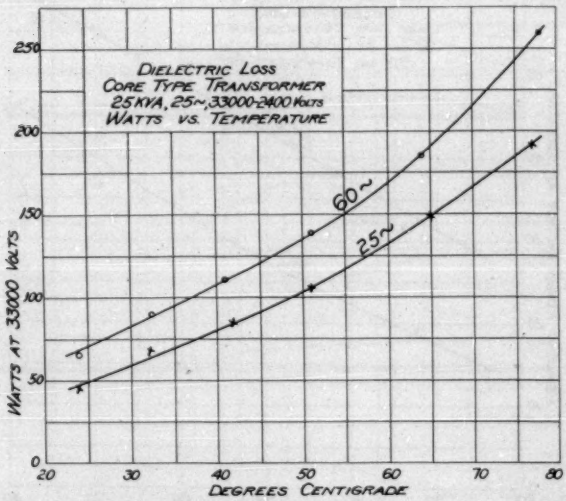
in the same class of apparatus, and are usually negligible, so far as the efficiency of the apparatus is concerned. It should also be noted that, even though the losses measured on some materials are many times those on others, the materials with the higher losses may be entirely satisfactory for the purposes for which they are used.

Our results would indicate that materials treated with varnishes and other compounds requiring drying or curing of any

kind show markedly higher losses than the same materials saturated with fluid insulators, such as transformer oil. While the whole field has not by any means been covered, we believe this can be taken as a general law.

This test has many limitations, both on account of the comparatively elaborate methods necessary to make such measurements and on account of the fact that there are many insulators and many kinds of apparatus to which it is difficult to apply.

FIG. 39.

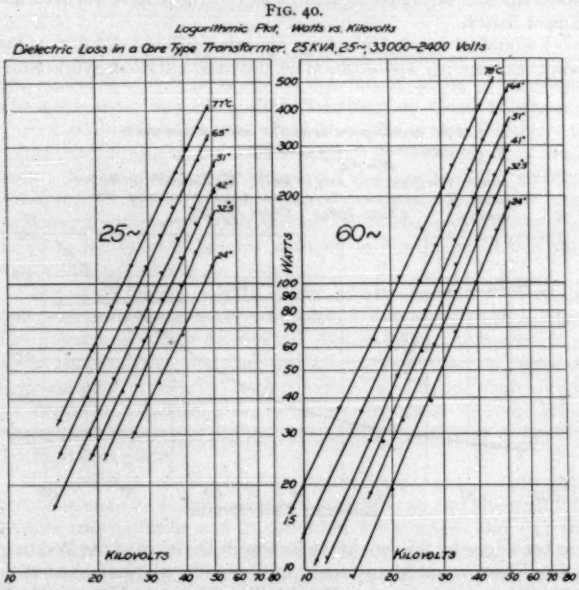


The method is very valuable for the evaluation of new materials and the control of the processing of many other materials. The changes in the losses, for example, are usually very great with the materials which require curing, whether this curing be the drying out of moisture, the oxidation of drying oils, or the carrying on of chemical changes which are very often necessary during the application of binders, fillers, and coatings, to other insulating material.

One of the most valuable characteristics of this test is that

by its means, determinations may be made of the condition or quality of an insulating material or structure which would not stand the ordinary dielectric strength test without actually breaking the insulation down; and then by further treatment this same material or structure may be put into satisfactory condition. This test also confirms in a very striking way the well-known fact

FIG. 40.



that the insulation of electrical apparatus is usually in its worst possible condition when apparatus is first put into service. The drying out due to service, as a rule, results in much better conditioning of the insulation than can be obtained during the manufacturing process without very extensive and expensive processing.

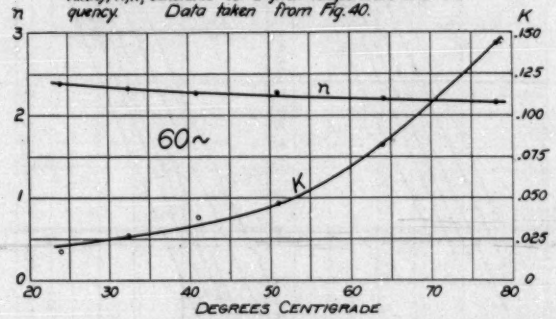
In conclusion, it should be said that a more general application of the dielectric loss test will result in a much better knowledge of dielectrics in general, and the time is probably not far distant

when such losses will regularly be measured by one or more of the methods which are being developed in the laboratories of the manufacturers and users of insulating material. By the use of these measurements, engineers will be enabled to figure their dielectric losses just as they now figure iron and copper losses, and they may have as definite specifications for the losses of insulating materials and insulated structures as they now have for iron and copper losses.

I would be unmindful of my opportunities if I did not, at this point, express my appreciation of the most excellent work which

FIG. 41.

Curve showing the variation with temperature of the constants in the equation:
$W = KE^n$
where W = Dielectric loss in watts; E = Kilovolts (effective value); K, n, constants for a given temperature and frequency. Data taken from Fig. 40.



has been done by the men in the Research Division of the Westinghouse Electric and Manufacturing Company who have had to do with this investigation. Dr. Phillips Thomas, Messrs. D. G. Howard, C. A. Butman, J. E. Mateer, and others have done much of the work leading up to the final development of instruments and methods. Mr. H. L. Cole has collected and edited the theoretical considerations which are given in this paper, and has also carried out practically all of the actual tests which have been recorded. Prof. H. B. Smith, of Worcester Polytechnic Institute, has given valuable counsel and help during the progress of the work.

ENZYMES IN THE FERMENTATION INDUSTRIES.*

BY

LEO WALLERSTEIN,

Wallerstein Laboratories, New York City.
Member of the Institute.

It is self-evident that the organic substance that is burned up into carbonic acid by this respiration means a loss of substance which amounts, in well-conducted malting, to about 5 per cent.

For economic reasons, it must be to the brewer's interest to reduce burning-up of his malt substance by breathing to a minimum. By retarding or moderating the growth of the embryo, through limiting the air supply and by comparatively low temperature, a sufficiently large production of enzymes may be produced in the malting process without an inordinate loss in substance through excess of growth.

The last step in malting is the kilning process. After the germination has sufficiently proceeded, it is interrupted by kilning. The green malt is first deprived of part of its moisture-content at lower temperatures, and then the kilning is finished at temperatures ranging from 175° to 210° F. The heating and kilning are done, as a general rule, by direct fire gases in large kilns, where the material is put in several stories so that a gradual heating takes place.

The objects of the kilning process are: (1) to interrupt germination; (2) to remove excess moisture, so that the malt will become transportable and in condition for storage; and (3) the production of the characteristic malt flavor and aroma.

The malt grain, after kilning, has gained in volume, and is about 30 per cent. larger than the barley corn.

I wish to point to some significant changes of enzymatic nature during kilning. In this rather long-drawn-out process of drying and kilning of the wet malt the enzymes, the production of which, of course, was the main objective of the malting operations, are found to run the gamut of a wide range of more and more raised temperatures, even finally rising to 85° to 98° C.

*Concluded from page 556, May issue.

Now, we have repeatedly noted the limitations of enzymes in enduring high temperatures, and we should therefore be curious to know what happens to our enzymes during the kilning.

At first, enzymatic actions are much on the lines as in malting; but when temperatures of 45° to 50° have been reached, developments in the sense of enzymatic reversions play a great rôle.

For instance, invert-sugar in part becomes again converted to saccharose; and some fermentable sugars are re-transformed into unfermentable polysaccharides. Similarly there are reversions which the albuminous bodies undergo that had previously already been degraded; they are re-transformed into real coagulable albumins. To some extent even the actual destruction of enzymes occurs in kilning.

Amylase is not affected by temperatures that will affect proteases, while the cytase, which, as we have seen, has to perform the work of breaking down the starch-cell walls, is completely destroyed during the kilning.

MASHING PROCESS.

The next step is the preparation of the wort by the mashing process.

The largest part of the malt endosperm is still insoluble in water, but in such form that most of it can now be readily transformed into soluble compounds during mashing.

The object of the mashing process, therefore, is to make such insoluble substances soluble by continuing and regulating the enzyme actions started during malting in such manner that the dissolved substances will be finally found in the finished wort, in the desired quantities and proportions.

For that purpose the crushed or ground malt is mashed in with water of suitable temperature (as a general rule, about 40° to 50° C.), and under these conditions the enzymes contained in our malt at once begin their work. The proteolytic enzymes act on the proteins, the amylase begins the conversion of the soluble starch into maltose and dextrines, the phytase attacks the organic phosphor compounds.

As pointed out before, the action of the amylase depends to a great extent on the temperatures, and we can therefore influence at will the ratio of maltose to dextrines in the wort.

It is apparent that it is one of the arts of the brewer to so regulate his mashing temperatures that the resulting wort will have the proper composition for the specific type of beer he desires to produce.

For beers which will be higher in alcohol and low in residual extractive substances the mashing process is so conducted that amylase will form large quantities of the readily fermentable maltose, by mashing for a considerable time at a temperature between 55° and 60° C. On the other hand, if it is desirable to make beers low in alcohol and high in unfermented extract, the mashing process is so modified that part of the diastase is destroyed and the rest allowed to act at higher temperatures, thereby producing a wort rich in dextrines.

At this stage I wish to point out that the malt will, under proper conditions, saccharify not only its own starch but additionally large quantities of added starchy material.

In the American practice of brewing, about one-third of the total material is used in the form of unmalted cereals, of which a separate mash is made; the amylase contained in the malt readily converts this extra quantity of gelatinized starch into maltose and dextrines.

In the distilling industry it is desirable, for economy's sake, to work with as little malt as possible. It is therefore obviously advantageous to employ a malt which is very rich in amylase, and for the purpose of distillery malts are kiln-dried very carefully, so as not to destroy any appreciable quantities of the amylase. In distillery practice, one part of good malt should be able to convert, besides its own starch, eight to nine parts of corn, the starch of which has previously been gelatinized by cooking.

As we have pointed out before, the action of all enzymes is greatly dependent on the reaction of the medium, be it acid, neutral, or alkaline.

In this connection, the composition of the brewing water is of far-reaching influence on the diastatic and proteolytic action during the mashing process. If we prepare a wort with distilled water, we find the same to react slightly acid toward litmus, due to its content of primary phosphates; in practice, the mineral salts contained in the brewing water have a tendency to either increase this acid or decrease it, and thereby influence the course of the mashing process. Alkaline waters—those containing cal-

cium, magnesium, or sodium carbonate—have a retarding influence on the enzymatic action, while waters containing calcium sulphate and calcium chloride, through their interaction with the phosphates, increase the acidity of the mash and have a favorable influence on the action of the enzymes.

In this respect I refer to the work of Fernbach and Huber, as well as of Windisch and Derz.

During the mashing process the action of the proteolytic enzymes is also of great importance, and the proper running off of the wort (its filtration) depends to a large extent on the way these enzymes have performed their work.

On the other hand, if, through carelessness, the mashing process is not conducted correctly (that is, if either the amylase or the proteolytic enzymes are not allowed to act under conditions to do their work properly), a great many difficulties are liable to occur in the subsequent stages of the process.

For instance, one of the difficulties which formerly gave much trouble to the brewer is starch turbidity, due to incomplete saccharification, caused, for example, by faulty mashing temperature, which caused destruction of the amylase before same had done its complete work. Nowadays it is a rare occurrence.

Of more frequent occurrence is the turbid running off of the wort, and, in consequence, difficult clarifications of the beers. This fault is usually due to an insufficient modification of the proteins during the malting process, particularly if in mashing the action of the proteolytic enzymes has not been sufficiently facilitated.

For such malts it has been found necessary to conduct the mashing process for several hours at a temperature of about 40° to 50° C., to give the proteolytic enzymes favorable conditions of time and temperatures. But there are also cases, though rare, where very high mashing temperatures from the beginning are indicated; for instance, in working up malts which might be termed "over-malted."

All this only confirms what I pointed out, that mashing is really a continuation and a bringing to a conclusion of all those changes that have been started in the process of malting.

After the mashing process is completed, the wort is separated from the dregs and boiled with hops. Thereby all the enzymes contained in the wort are destroyed and a separation of the coagulable albuminoids takes place.

FERMENTATION.

The boiled wort is cooled to a temperature of 7° to 10° C. and about one pound of fairly thick yeast per barrel of 31 gallons added.

After a short time the yeast begins to sprout, fermentation sets in, and a gradual splitting up of the sugar into alcohol and carbonic acid gas takes place.

Simple as this reaction appears, it is really a highly complex process, and only within recent times has it been recognized that it is the result of a number of complicated enzyme reactions.

For more than two centuries have the most astute scientific minds been engaged in the task of elucidating the laws underlying the phenomena of fermentation, and a short review of the history of our knowledge of fermentation may not be out of place.

In 1680, Leeuwenhoek, the Dutch scientist, who had designed a magnifying glass of marvellous perfection for the time, proved that yeast was composed of small globular bodies, which he thought were possibly of a vegetable nature; but he drew no further inference as to their function.

The fact that only sweet liquors were liable to ferment had been observed and specially dwelt upon by J. J. Becher, in 1682, but it was not until one hundred years later that Appert, a French cook, hit upon an ingenious method for conserving sugar-containing articles of food by preventing their fermentation.

By Appert's method, which has made its author famous, articles such as grape-juice, etc., were put into completely filled bottles. The bottles were then placed in water, which was gradually heated to boiling, and were then tightly corked and allowed to cool, when, of course, the contracting liquid left a vacuum space near the top. Naturally the grape-juice, etc., thus preserved kept indefinitely, but was again liable to souring or fermenting after the bottle had been opened.

Appert and his contemporaries concluded that contact with air was the cause of fermentation or souring of fruit juices and similar substances.

This theory that fermentation was caused by oxygen was further developed and championed by the famous French chemist, Gay-Lussac.

About 1835–1837, or seventy years after Appert's discovery, several German and French chemists successfully disproved the

oxygen theory: it was especially Theodor Schwann who in 1837 demonstrated that if air is heated, or passed through highly corrosive liquids, like strong sulphuric acid, it loses its power to incite fermentation. Sugary liquids previously heated and brought in contact with air so treated did not ferment, while with ordinary air they did show fermentation.

At this time (1836) Berzelius had already expressed himself in the following highly significant manner: "In processes observable in animal or vegetable life, certain bodies possess the faculty of influencing compounds in a manner entirely different from ordinary chemical affinity, by causing in such compounds a decomposition or rearrangement of parts without themselves or without any constituents of theirs partaking therein." Berzelius proposed for these phenomena the term "catalytic action."

Liebig, three years later, in 1839, said: "Fermentation is not a physiological or life process, but is caused by the peculiar property of a ferment contained in yeast, which ferment is in a state of constant motion, changing and transferring this motion to the sugar." He called this action "contact action," because the ferment infects sugar with its own instability by contact.

Liebig's statement, emanating from such high authority, dominated chemical thought for twenty years or so, and therefore scant attention was paid to other interesting observations, as, for instance, to the fact, proved by Schroeder and Dusch, that sugar-containing solutions could be indefinitely preserved in contact with air, if the latter has been previously filtered through cotton wool. I will mention also the significant observation by Hemholtz that alcohol fermentation is not transmitted through membranes.

Then, in 1857, Pasteur made his famous announcement that in every case of alcoholic fermentation the development and increase of cells could be observed; that fermentation represented a life act, a process dependent on and indissolubly accompanying the life-cycle of an organism; and that it was not a phenomenon of any so-called contact action, wherein the transformation of sugar is caused by the presence of a ferment which itself remained unaffected. This was in strongest contrast to Liebig's theory, who had all along made his contact substance appear a product of destruction or disintegration of the life of the cell, whereas Pasteur laid emphasis exclusively on the growth of the cell and

made the fermentation appear a direct function of the physiological phase.

In support of his view, and especially to bring proof that contact action with bodies derived from yeast could be had outside the living yeast-cell, Liebig showed that a water extract made from yeast possessed the property of converting cane-sugar quantitatively into invert-sugar, and explained that possibly the yeast-cell might, in its life process, produce those contact bodies that cause the cleavage of sugar into alcohol and carbonic acid, but that the life process as such had no relation to fermentation. On the other hand, Pasteur, even two years after Liebig's death, still maintained (1875) that the chemical process of fermentation was essentiallly dependent on the life act, with which it begins and ends.

To-day we may say that, although Pasteur's great work has firmly established the fact that fermentation is inseparably connected with the life and growth processes of the yeast-cell, yet the distinction indicated by Liebig between the substance causing fermentation (enzyme) and the yeast-cell which produces it has been borne out since.

The first man definitely to formulate this merely chemical enzyme action as being basic for all fermentation processes was really Moritz Traube, who (1858) stated: "Yeast acts upon sugar not in a physiological way, but simply by ferments, which it separates, similarly to sprouting seeds that secrete diastase, or almonds which give off emulsine."

Traube had not brought proof to support his theory in the field of alcohol fermentation; in fact, though Liebig himself had succeeded in performing enzymatic operations (invertase) by means of yeast extract, real fermentation outside the living yeast-cell remained unaccomplished. As early as 1846, Luedersdorff, also Schmidt, had tried to destroy yeast-cells by crushing, but no fermentation resulted when they added the destroyed cells to a sugar solution. Other investigators tried to obtain juice from yeast by pressure, but never succeeded in getting the liquid entirely free from living yeast-cells. Others, like Naegeli, applied certain menstruums, such as glycerine, for extracting the contents of the yeast-cell. All experiments were unsuccessful and modified fermentation theories always followed.

To furnish the correct answer was reserved to E. Buchner,

who, in 1897, by more exact work and technical perfection, prepared an extract or juice from yeast entirely free from living yeast-cells. Buchner triturated yeast with quartz sand and infusorial earth, and then subjected the mass to high pressure in an hydraulic press. The resulting yeast juice contains zymase, an enzyme that will produce alcoholic fermentation outside the living cell.

Zymase is not the product of disintegration of the living yeast-cell, but, on the contrary, its formation is most intimately connected with, and dependent on, the growth of the living cell and its physiological functions.

Inasmuch as this cell-freed yeast juice, as produced by Buchner, will cause alcoholic fermentation, the theory of Liebig that fermentation in itself, as a merely chemical process, is separable from the physiological functions of the cell, stands strongly supported.

Returning to our short description of practical brewing operations, you will recall that we had pitched the wort with yeast. Fermentation in the case of lager beers, we find, is completed after eight to ten days, after which the yeast settles to the bottom of the vat.

Microscopical examination would show that, after pitching, each drop of wort contains about forty yeast-cells, while during fermentation the number of yeast-cells has increased to four or five times the original quantity. (One gramme of pressed yeast represents approximately 2,000,000 cells.)

It is a noteworthy fact that in the same wort and under the same temperature conditions ultimately the same number of yeast-cells is found after fermentation, immaterial of the larger or smaller quantity of yeast originally added to the wort.

The most striking change which takes place during the eight- to ten-day period of fermentation is the decomposition of the fermentable carbohydrates into alcohol and carbonic acid. However, besides this main reaction, a great many other changes have occurred.

On the one hand, part of the peptones, amino-acids, and mineral substances have been taken out of the wort by the yeast and used for the building up of new protoplasms, while, on the other hand, protoplasmic substances and products of metabolism are diffused from the yeast-cell into the beer; for instance, cer-

tain organic acids, glycerine, aromatic substances, etc., all of which are found in the finished beer.

The yeast itself, which settles to the bottom of the fermentation vat, is used for subsequent brews.

This short outline refers to bottom fermentation beers, so-called "lager" beers. Another process, wherein the yeast rises to the top of the fermenting liquor, from which it is skimmed for the next fermentation, is termed "top fermentation process," and is used for ales, stouts, and similar brews.

Top fermentation is conducted at much higher temperatures, frequently at 20° to 25° C.

The yeasts used for these two processes represent two distinct varieties, called bottom fermenting yeast and top fermenting yeast; although they are hardly distinguishable under the microscope, they show great variance of work at each other's temperature conditions.

Besides the two yeast races mentioned, there exist a large number of other yeasts, so-called "wild" yeasts.

First to investigate the merits and coexistence of these various races was the late Prof. E. C. Hansen, who, in 1883, showed that, beside the culture yeast, a number of these wild races did exist, and that the latter were far more frequently causes of trouble in brewing than any disease caused by bacteria infection. Hansen's classical investigations led him to the invention of his famous pure culture system, whereby pure races of yeast have been cultivated and the most far-reaching and beneficial change for the fermentation industries resulted.

The basis of Hansen's ingenious method is the isolation of individual yeast-cells and by rigid precautions propagating them in absolute race purity.

I have mentioned before that when the wort is pitched with normal yeast quantities it contains about forty cells to one drop. Hansen diluted this mixture so that only the third or fourth drop could contain one yeast-cell, and by adding to a number of bottles containing sterilized wort just one drop per bottle he made it possible that not any bottle could contain more than a single yeast-cell.

After two or three days, this individual cell had sufficiently multiplied to form a colony, which was carefully examined as to

its race purity, and, if approved, was employed for gradually producing a large quantity of yeast.

Other methods have since been proposed for pure yeast cultures which have been very successful; as, for instance, Lindner's droplet culture.

Let us discuss in some detail this enzyme-producing yeast-cell, its property and its mode of reproduction.

The yeast-cell, though probably more closely studied than any other living organism, offers no striking features in its life-cycle differing from any other similar plant-cell. In its propagation it reproduces itself by budding; that is, a small protuberance appears on the cell, quickly increases in size, and after it has attained the dimensions of the parent cell it becomes detached, and the separated daughter cell in turn reproduces itself by the same process.

Like all other living organisms, the yeast must have oxygen for its existence, without which it will unfailingly perish.

In the course of Pasteur's studies on the breathing of the yeast the savant had given a highly original and entirely new insight into the whole question of respiration in the low organisms.

Pasteur discovered that with a copious supply of oxygen yeast would propagate and cause fermentation, but that with oxygen completely shut off it not only continued to grow but its fermentative capacity was much higher than in the case where fresh air was supplied.

Pasteur defined fermentation as life in the absence of air. Then how is it that organisms do not perish under these conditions, according to our previous statement? Pasteur discovered that a large class of lower organisms depend for their breathing supply on oxygen, which they derive from organic compounds, albumins, etc., which they split up and thus forcibly compel to furnish them with the oxygen needed. These organisms he called "anaërobic," as distinguished from "aërobic," or those using atmospheric oxygen.

Here in Philadelphia, in your municipal experiment station for sewage disposal, at Spring Garden, you have a centre from which, as applied to the special field of sewage disposal, concise knowledge and proof of these conditions have been spread everywhere.

The anaërobic bacteria, in their breaking-up work, cause

putrefaction, as is evidenced by the bad smells of sulphur compounds, which are volatile decomposition products of the albuminous bodies which they attack. It was stated in the records of the Spring Garden investigations, extending mainly through the years 1909 to 1911, that in one cubic centimetre, say twenty to twenty-five drops of sewage, no less than three to four million of these anaërobic bacteria were counted, all voraciously bent upon devouring the albuminous food contained in the city sewage.

These anaërobic bacteria, however, cannot possibly live where even only a very moderate amount of free oxygen is dissolved in the liquid. Therefore the gist of all sewage disposal into rivers or water lies in the maintaining of a slight oxygen balance so that eventually only the aërobic bacteria might exist. These aërobic bacteria or fungi likewise feed on albumin, etc., but they lack the faculty of breaking up these albumins for breathing purposes.

Pasteur stated that yeast was an organism, capable of living under both kinds of conditions, but that it was only as an anaërobe that it functioned at all as an alcoholic ferment. I quote Pasteur's own words: "Fermentation by yeast (that is to say, by the type of ferments properly so called) is presented to us, in a word, as the direct consequences of the processes of nutrition, assimilation, and life, when these are carried on without the agency of free oxygen."

Many tests have since been undertaken further to investigate these phenomena: for instance, H. Buchner and Rapp experimented to determine whether sugar could be fed to yeast without forming alcohol, under conditions where the maximum access of air came into contact with each particle of yeast. They found that under these conditions one-seventh of the sugar was used for respiration, while six-sevenths was transformed into alcohol.

The important practical problem, whether in brewing and alcohol fermentation generally it were better to work with more or less air or with no air at all, has been definitely solved in the sense in which Pasteur already answered this question, that, with abundant air furnished, the sprouting or body growth of yeast goes on at a much faster rate than when less or no air is provided, but that the fermentative power, pound for pound, is much larger when air is excluded.

These and similar investigations have been very helpful in developing the large industrial branch of compressed yeast manu-

facture. In Europe, especially in England, Germany, France, etc., yeast is very largely employed instead of baking powder in bread-making, and the process of yeast manufacture by "aëration" dominates.

I will now in a few brief remarks refer to the food requirements of yeast. For this phase we are well prepared because of our insight gained into the changes and accomplishments in the steeping, malting, and mashing processes. The mash after boiling constitutes an ideal liquid for the nourishment of yeast. We have the various carbohydrates in the proper form; there are also the amino-acids and other nitrogenous bodies so important for the building up of the protoplasm of the cells; considering that yeast in the dry form consists of more than half of albuminous matters, equivalent to about 8 per cent. of nitrogen. The wort also contains the very necessary phosphates and potassium, magnesium, and calcium salts.

You will remember that the wort, before the yeast was added, had been boiled, and therefore all the enzymes contained therein were destroyed.

This simplifies matters in so far as all enzyme functions from now on are within the yeast-cell or, at any rate, originate there.

Let us be thankful even for this little simplification. The process in itself is so complicated that any simplification is more than welcome. Slowly the scientific investigators are now elucidating the complex working of the stupendous organization seated in the yeast-cell and how the cell manages its enzymatic staff; already the presence of seventeen enzymes therein has been established, but very likely there are a great many more.

There is catalase, which decomposes hydrogen peroxide; there is maltase, the enzyme that converts maltose; there is invertase, the enzyme that splits up cane-sugar and converts it into dextrose and lævulose; there is glycogenase, which attacks glycogen; and others. However, there is no amylase present, and starch degradation is henceforth precluded. Of the greatest importance are the proteolytic enzymes of the yeast. The principal one, also contained in Buchner's press juice, called endotryptase, has been diligently studied, and ranks in general importance with pepsin and trypsin, but is really different from both. It is very powerful, digests fibrin, egg-albumin, casein, etc. It degrades albumin very much like trypsin; in fact, it goes even further in splitting up of

albumin into simpler bodies; its optimum working conditions, however, are more like those under which pepsin acts, as it requires a slightly acid medium for its best activity.

Under normal cell conditions, endotryptase will not diffuse from the living yeast-cell, and therefore its activity takes place only within the cell itself.

If for any reasons the fermentative activity of the cells has ceased—for instance, because of abnormal temperatures or lack of sugar—then this powerful endotryptase forms a certain menace to the life action of the yeast itself. It begins to attack and to decompose the protein compounds of the cell itself, including the enzymes, especially those responsible for the fermentation (zymase). This process is called "yeast autolysis."

The destructive action of the endotryptase towards zymase is also apparent in Buchner's press juice, which on standing gradually loses its fermenting powers.

Buchner, however, made the remarkable observation that if to the pressed juice a quantity of pressed juice which has been previously boiled is added, the zymase will remain active for a much longer time. He came to the conclusion that the gradual destruction of the zymase on standing is due to the activity of the endotryptase, which decomposes the zymase; and that during the boiling of the juice an antitryptase is formed which prevents the endotryptase from attacking the zymase. He also proved that this anti-tryptase will protect casein and other albuminous substances from being attacked by the endotryptase.

I now wish to describe in further detail the workings of the "zymase."

The zymase, as stated before, is contained in Buchner's pressed yeast juice, also in Lebedew's maceration juice.

Lebedew's method is as follows: Brewers' pressed yeast is spread out in thin layers, about 1 cm., and dried at a temperature of 25° to 30° C., which takes about two days. The slow drying so changes the cell conditions that when this dried yeast is macerated with a small quantity of water at about 35° C. for four hours the zymase becomes diffusible and goes in solution. It is filtered, and the filtrate contains, besides other yeast enzymes, also zymase. I have here a sample of such maceration juice, and will show you a few experiments with it.

By adding to sugar solution some of the maceration juice,

fermentation was induced. Another experiment showed the instantaneous decomposition of hydrogen peroxide by the catalase contained in the Lebedew maceration juice.

Recent investigations, particularly those of Harden and Young, have done much to give us a clearer understanding of the mechanism of the working conditions of this zymase.

One of the facts established by these investigators was that by filtering the fresh juice at a pressure of 50 atmospheres through a Chamberland filter, which was impregnated with a 10 per cent. gelatine solution, they could separate the juice into two parts, one remaining on the filter and a clear liquid passing through. They found that with neither of the two separate parts could they bring about fermentation, but made the highly important discovery that if both are mixed the fermentative power was again restored in the mixture. They also found the fact that the filtrate could even be boiled and still retain its power to cause fermentation after mixing same with the residue that had remained on the filter.

Harden and Young thereby established the important fact that zymase needs for its working efficiency an "activator," which they termed "co-enzyme," and which can be separated from zymase by proper filtration, and which is not destroyed by boiling.

Another momentous result from the work of the same investigators was to ascertain the intimate relation of the phosphates to the action of the zymase.

First, they had observed that when sugar solutions were undergoing fermentation by the addition of Buchner's pressed juice they could, by adding alkaline phosphates, bring about an increase in the evolution of the carbonic acid gas.

They then discovered the fact that a definite relation exists between the amount of phosphates added and the volume of carbonic acid evolved. In other words, they proved that when the alkaline phosphates were added in a certain quantity formation of alcohol would be engendered in analogous amounts.

The authors have given the following explanation, which is now generally accepted:

The zymase does not act on the sugar directly, but on a rather loose combination of sugar with a compound of sugar and phosphate, the hexose-phosphate. This intermediary loose combination is the result of the action of an enzyme, phosphatese, which

is contained in Buchner's pressed yeast juice, and has the power to form same out of two molecules of sugar and two molecules of phosphate. Only after this loose compound has been formed will the zymase begin its fermentative action by attacking it and splitting off the one molecule of sugar, decomposing the latter into carbonic acid and alcohol, while the hexose-phosphate, which is composed of two molecules of phosphate and only one of sugar and which is a rather stable compound, remains.

$$2C_6H_{12}O_6 + 2PO_4HR_2 = 2CO_2 + 2C_2H_5OH + 2H_2O + C_6H_{10}O_4\ (PO_4R_2)_2$$

This residual hexose-phosphate is now acted on by another enzyme, the phosphatase, which again disrupts the hexose-phosphate into dextrose and phosphate.

$$C_6H_{10}O_4\ (PO_4R_2)_2 + 2H_2O = C_6H_{12}O_6 + 2PO_4HR_2$$

Thus having restored the phosphate and half of the dextrose to their original form, the cycle of operation begins anew by the "phosphatase" acting upon the two molecules of phosphate and two molecules of dextrose to form the above combination once more. Thus, by an endless chain of operations, the same amount of phosphates is made to do a large fermentation work over and over again.

This cycle of fermentation functions is illustrated in graphic form on page 730.

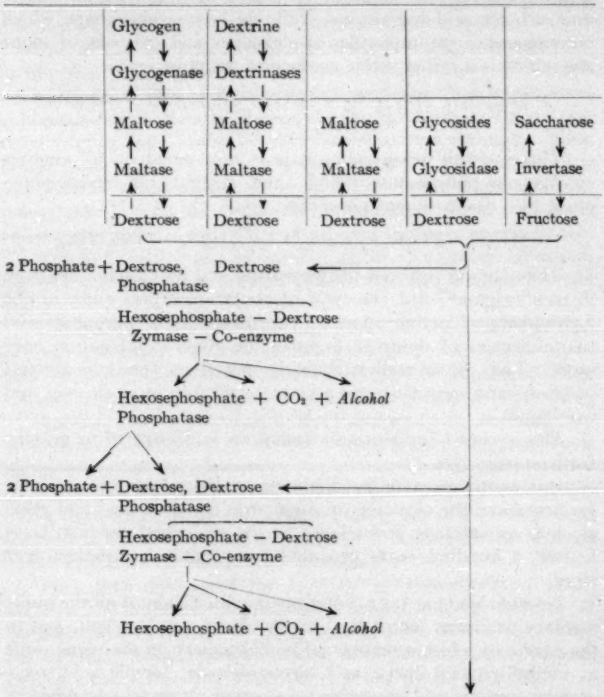
It is worthy of note that the main or end reaction in alcoholic fermentation, the cleavage of sugar into carbonic acid and ethyl alcohol, was already formulated by the renowned chemist, Gay-Lussac, a hundred years ago, and has remained unshaken ever since.

It would lead too far to enter upon a discussion of all the intermediary processes which lead to the above simple result, and in the course of which a number of bodies appear on the scene, such as methyl-glyoxal, lactic acid, acet-aldehyde, formic acid, oxy-acetone, pyruvic acid, glycerine, etc.—some ultimately detached as waste products—of which we now know that they are landmarks of those intricate processes.

A number of fermentation schedules have been advanced for elucidating this field. Thus, according to Schade and Ehrlich, an isomeric lactic acid is first formed from the sugar, the acid sub-

sequently splitting up into acetaldehyde and formic acid, which two bodies, by interaction, then form alcohol and carbonic acid.

However, many probabilities speak for the greater correctness of the view advanced by Kostytschew and Neuberg, that the pre-



liminary cleavage of sugar leads first to pyruvic acid and loosely-combined hydrogen; the pyruvic acid is then by an enzyme, carboxylase, split into acet-aldehyde and carbonic acid, and the acetaldehyde becomes promptly reduced to alcohol by the hydrogen previously activated by means of a reductase.

I have previously stated that besides alcohol and carbonic acid other substances are formed during alcoholic fermentation, and among these I wish to specially call attention to the higher alcohols, or fusel oils.

For a long time the formation of these fusel oils could not be explained; within recent years, however, this mystery has been completely cleared up by the remarkable investigations of Felix Ehrlich. We have noted before that the wort contained considerable quantities of amino-acids, and he proved that these higher alcohols are due to a decomposition of these amino-acids. The yeast has the faculty to split off the ammonia from the amino-acids, using same as nitrogenous food, and at the same time the corresponding higher alcohols and carbonic acid gas are formed.

The important fact that the yeast-cell also has the power to synthesize its albumin for its cell substance directly from the ammonia, sugar, and inorganic salts is not new and had already been observed by Pasteur. This synthesis of albuminous substances with ammonia as nitrogen source is probably also brought about by enzyme action within the yeast-cell.

It has of late become of great importance in Germany, where enormous quantities of yeast are now manufactured from ammonium sulphate, phosphates, and sugar, the yeast being dried and used for cattle feed. We have here a process in which, in less than 24 hours, large quantities of inorganic nitrogen are changed into a form readily available for feeding purposes. This process has assumed great economic importance.

In quite an analogous way the commercial production of ethyl alcohol depends up zymase action, and the enzyme actions involved are very closely related to those of the brewing industry.

The commercial production of alcohol in this country starts either with corn as a raw material or with molasses. In using corn as a raw material, as previously stated, the starch therein is saccharified by means of malt and changed into maltose and dextrines. This saccharified mash without filtration is then allowed to undergo alcoholic fermentation. If this fermentation is well and properly conducted, the residual amylase is not destroyed and will saccharify the major part of the dextrines contained in the mash, which then will also be split into alcohol and CO_2 by the fermenting yeast. Fermentation temperatures are much higher than those employed in brewing, the temperatures

usually running approximately from 20° to 30° C. The yeast used belongs to the top fermenting variety.

The other important commercial raw material in the production of alcohol is molasses. During the fermentation of molasses mashes the yeast must first secrete sufficient quantities of invertase to change the cane-sugar into invert-sugar, which is then readily split up into alcohol and carbon dioxide.

Entirely different are the enzyme actions involved in the production of vinegar, lactic acid, and butyric acid.

Two processes are known for the production of vinegar: The slow vinegar production, called the "Orleans" process, and the "Quick" vinegar process ("*Schnellessigfabrikation*"). In the case of vinegar the enzyme action is an oxidizing action. By the instrumentality of acetic acid bacteria which produce the enzyme alcoholase, the dilute alcohol (5 to 12 per cent.) is directly oxidized by atmospheric oxygen to acetic acid. In the formation of lactic acid, the lactic acid bacteria form an enzyme which at relatively high temperature (up to 50° C.) changes the sugars into lactic acid. Similar is the production of butyric acid by the butyric acid bacteria.

Let us now again return to our practical brewing operations.

The fermented beer is stored for a number of weeks, during which time it clarifies, and is then finished by being impregnated with carbonic acid gas and filtered.

The part of the beer which is to be sold as bottled beer is then pasteurized by heating in the bottle to 140° to 150° F. for about half an hour.

Formerly beer was served from the keg, the bottling done being primitive. Such beer, whether bottled or not, was intended to be, and was, as a rule, consumed shortly after it left the brewery. With the development of the bottling industry, however, a change in the methods of consumption ensued. Bottled beer began to be shipped long distances from the brewery, and, instead of being consumed soon after it left the brewery, was kept for considerable periods of time.

It was soon found the well-brewed beers under conditions of long shipment and storage developed microörganic growths. The brewers therefore adopted the process of pasteurization; *i.e.*, the beer in the bottle was subjected to a temperature of from 140° to 150° F. for about half an hour. While pasteurization prevented

the growth of microörganisms, it was found that pasteurized beer was particularly sensitive to cold and was unstable.

It is customary in this country to drink bottled beer very cold, the bottles being usually kept on ice for a considerable time before consumption.

This chilling causes beers to deteriorate, lose their brilliancy, and to become hazy or cloudy. Prolonged keeping at ordinary temperatures has much the same effect on brilliant bottled beers. While pasteurized bottled beers vary in their keeping qualities, as a rule, if kept at ordinary temperatures for from six weeks to three months, they become hazy and cloudy, and then usually deposit a sediment.

The production of a beer which did not cloud on ice, and which would remain brilliant in the bottle and without sedimentation, was the important technical problem which faced the brewer in recent years. Many theories were put forward to explain the causes of this peculiar behavior; the general opinion was that the trouble was due to undesirable albuminoids contained in the beer.

To overcome these difficulties, the brewers tried to eliminate as much as possible these so-called "undesirable albuminoids" by the freezing-out process; that is, subjecting the beer to very cold temperatures and subsequent filtration.

Such treatment improved only slightly the chill-proofness and stability of the beer, and was not a satisfactory solution. Important constituents were thereby removed from the beer, and the resulting product tasted empty and lacked foam-keeping quality.

I eventually found the solution of the problem. I discovered that, if a proteolytic enzyme—for instance, pepsin—or any other that is active in a slightly acid medium, is added to the beer, subsequent to the boiling of the wort, in extremely small quantities, it will render the beer chill-proof and stable.*

The small quantity of one gramme of pepsin added to one barrel of beer will accomplish this purpose. I also found that the addition of an excessive amount of pepsin will not alone fail to chill-proof the beer, but will make the beer even more sensitive to cold and unstable.

I have also found that the enzyme is not destroyed during

* U. S. Letters Patent Nos. 995,820 and 995,824.

pasteurization, but retains its activity. It is astounding that the presence even of such a minute amount as one part of pepsin in one million parts of beer can still be quantitatively determined by the edestin test.

The analysis given below shows the effect of proteolytic enzymes on the various nitrogen compounds contained in the beer. No. 1 represents the original beer, No. 2 the same beer after the enzyme action.

	I	II
Albumoses	27.0 per cent	10.5 per cent
Peptones	21.1 per cent	28.8 per cent
Non-precipitable	51.9 per cent	60.7 per cent

This method is now almost universally adopted in the manufacture of bottled beers in many countries, and the large majority of American breweries are using this process.

I have tried to point out the important part which the enzymes play in the fermentation industries, and hope I have succeeded in making clear at least the more striking phenomena. In a subject so vast and complex as that of enzyme action, one can only hope, in a paper of this size, to dwell upon the major workings, and I hope that it will not fail to contribute to a better understanding of the rôle of the enzymes generally, and particularly in relation to the fermentation industries.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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TUNICATES.

A large number of Tunicates have been announced as giving light, and among them are some of the longest-known and most classical examples of the power. Some of these forms are still in question, and further observation, followed by research, is desirable to determine the extent of the light-producing ability among the group. Among the animals in which the power to light is well known and in which it has been studied with care, one of the groups of Tunicates, the genus *Pyrosoma*, stands out prominently. So far as known, all the members of this genus are luminous to a powerful degree.

This animal lays fertile eggs in its brood pouch, and the egg develops into the primary individual, called the cyanthozoöid by Huxley. At about the time the egg or embryo is cast out into the sea to live its own life, this cyanthozoöid begins to give off buds, first two and then two more, making four. These buds grow into young, perfect individuals, and the budding goes on until a vast number have been formed, all still connected more or less, and lying in the same mass of tough, jelly-like substance, called tunicine, which is akin to chitin. In thus multiplying, the unit individuals become arranged to form an elongate cylinder of some few inches in length in the smaller species up to a number of feet long in the larger varieties.

Fig. 1 shows a photograph of the colony of *Pyrosoma elegans* from the Bay of Naples, Italy.

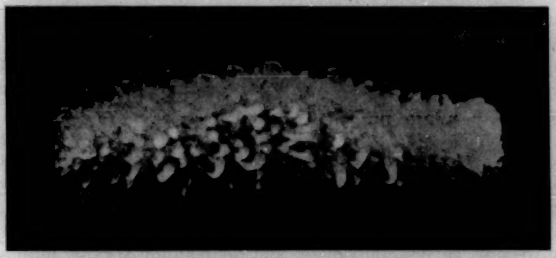
The cylinder has a central channel running from end to end of the colony and opening at both ends. The individuals that comprise the colony are placed in a radial position with their bases, on which the excurrent openings are found, forming the

* Continued from page 624, vol. 183, May, 1917.

bounding wall of the central canal, while their distal ends, into which the incurrent channel of the individual opens, is directed outward, forming a more or less projecting papilla in every case. These papillæ are well seen in the photograph. Each papilla reaches out from an elongate structure which is still considerably thicker than the papilla, so that a shoulder is formed at the point of junction. The branchial region of the anterior part of the digestive tract which lies in the main body reaches about to this junction.

Panceri, in several able papers, studied the lighting of the animal and found that this light came, not from the whole body but from two medium-sized masses situated in the sides of the

FIG. 1.



Photograph of an alcohol specimen of *Pyrosoma elegans*. (After Polimanti.)

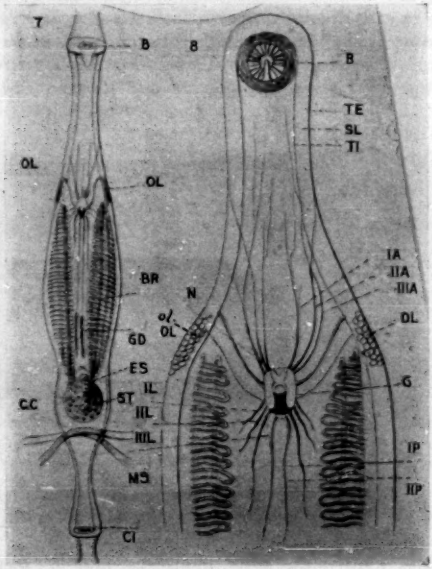
body just below the junction mentioned above (Fig. 2, *ol*). Examining the structures in both dark and daylight alternately several times, he found that these masses were those which had been incorrectly described by previous writers as ovaries, nephridia, lens-like bodies, and several other organs.

He further found that the masses were cellular in nature, but incorrectly took them to be fatty bodies. They have also been studied and described since that time by several other investigators, with but little progress until the work was taken up by Julin at Naples and Villefranche and more modern methods employed.

The study of ascidian structure has shown us that its body is covered by the thick test, and that underneath that test, but not very intimately connected with it, lies the outer epithelial layer

of the body. Most authorities agree that, contrary to our expectations, this test is not formed by the epithelium, but by certain mesodermal cells that have come through its surface and arranged themselves in various ways in the substance of the test. These cells are known as the " test-cells," and they have a peculiar

FIG. 2.



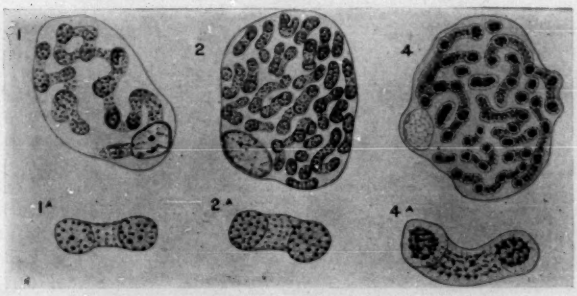
Drawings of two individuals of a colony of *Pyrosoma* (left-hand one on smaller scale). *Ol*, luminous cell-mass. (After Panceri.)

and recognizable structure that has been well described by Julin and which is exhibited by Fig. 3, copied from Julin's work on the subject. These cells are called " internal follicular cells " by Kowalevsky and " Kalymnocytes " by Salensky.

The test-cells lie in the test on the sides and ends of long channels which contain blood-vessels. Thus they are bathed by

the blood stream and are in a position to show an active metabolism. Julin's chief contribution to our knowledge of the luminous organs of *Pyrosoma* consists in the discovery of the fact that the large cells that form the mass are modified test-cells lying in a space in the test that represents one of the enlarged blood-spaces known as the peripharyngeal blood-space. In the young egg and embryo all of the test-cells are light-giving, but in the young tetrazoid colony a portion of them, in the region mentioned, grow in size, become differentiated in structure slightly, and attain to the power of intensive lighting, while the remainder lose the lighting power and become useful only as formative

FIG. 3.



1. Test-cell of *Pyrosoma*. 1*a*, enlarged portion of cytoplasmic inclusion; 2 and 4, light-cells; 2*a* and 4*a*, portions of cytoplasmic inclusions (light-organs of cells). (After Julin.)

elements of the substance of the test. They show fine streaming processes, passing into the test material, as in the case of cartilage, bone, and tooth-cells.

Julin has figured the adult light-cells, and his pictures are shown in Fig. 3, *2* and *4*. Here we see that it is a compact rounded cell of some size and that it shows a nucleus that is placed in some extreme side or corner of the cytoplasmic mass. In the majority of cases, especially in a young animal and with poor preparation, these cells show as small cells with a clear body and the nucleus placed over at one side. Panceri figures them thus, sometimes without even showing the nucleus. He took them to be fat-cells, and it is probably from observing these particular

structures that he came to the erroneous conclusion that the light-producing substance was a fat.

Julin studied them in well-made preparations and shows (see his figures shown above) that the cytoplasm is filled by an elongate, spiral, and branching tube that simulates a branching nucleus, being bounded by a membrane and showing a reticulum. He describes granules of some material as clinging to this reticulum, and these we must assume for the present to be the granules of photogenin. The light-cells show this structure and its granules in common with the ordinary test-cells from which they are derived and which are all, during the younger embryonic stages, capable of lighting. By the time the embryo or larva is ready to be thrown off to pursue its independent existence, the general test-cells have lost the lighting power and only the specialized test-cells can shine. Fig. 3, 1, 1*a*, represents a test-cell and part of its reticular light-mass under higher magnification.

The blood supply of the light-organs has been accounted for: they lie bathed in the blood stream of the peripharyngeal sinus. As to a nerve supply, none has been demonstrated, and yet all experiments and observations show that they must be operated by nerve supply from the cerebral ganglion. The animal lights freely upon stimulation, and is said at times, when in its natural habitat, to shine continuously and with great brightness. In this case a natural and continual stimulus is evidently present. Peron in 1800, Bennett in 1833, and Meyen in 1850, recorded the presence of great masses of *Pyrosoma* on the high seas, giving off a great light by which one could see objects on shipboard.

Panceri studied the light in 1871 in several species. He records the color, from his own observations and from those of others, as clear blue in *Pyrosoma gigantum;* as varying from red to orange, pink, greenish, and, finally, blue in *Pyrosoma atlanticum.* He also made some long-extended studies of its powers of lighting and the conditions under which it is exerted. In the main the results of these experiments were correct, and much that we know was learned from them. In some cases, however, mistakes in the method resulted in erroneous conclusions.

Recent works by Oswald Polimanti and Fritz Burghause give us the best idea of the lighting processes of *Pyrosoma.* Polimanti worked at Naples on a suitable supply of living specimens

of *Pyrosoma elegans* in the Naples Zoölogical Station. These specimens as found at Naples were from seven to ten centimetres long, although the species attains a length of over four metres in the Indian Ocean.

Pyrosoma, when brought into the laboratory and kept in a large tank of pure aërated sea-water of proper temperature (same as the sea temperature), lives well for some days and is normal in its reactions. It responds to many stimuli by exhibiting its beautiful light. This response is more full and intense than that of most other light-producing animals. When freshly dead or in process of ordinary dissolution it cannot be made to light, as is the case with some other animals, such as *Pennatula, Pholas,* or the *Lampyrids.* This appears to be due to the fact that the luciferine is not lasting or that it is freshly made for each exhibition, as in the ctenophores. On the other hand, that we are dealing with a substance that acts independently of any life-processes seems to be proved by the fact that the fresh living animals can be ground up or squeezed and the light material will then give a strong exhibition of light outside of the animal's body; also, by rapidly drying the substance, it can be preserved and later be made to give light by moistening it with fresh water or sea-water.

Polimanti states that at times the animal lights entirely spontaneously. This light may appear at only a few points, or the whole body may glow all over from the many points of light situated, two in the "shoulders" of each individual. Such a light well persist for a few seconds or minutes and then suddenly stop.

Panceri noted this fact and attempted to explain the communication of the lighting condition from one individual to others of the colony. He supposed that certain bands of muscle, common to the whole mass, did this in some way by their motion, but one can hardly accept this view of the case. We have seen in other forms that muscular action is entirely separate from the lighting power except as it acts indirectly by discharging the products or otherwise bringing them together, or as it results in forcing air or aërated blood into the light-tissues.

Some chemicals, as is often the case with other light-organisms, will cause the light to appear in *Pyrosoma.* They undoubtedly act on the creature's nervous system through pain,

shock, or in some other pathological way, and cause the light to appear in this way. Fresh water is particularly favorable for this purpose. When placed in this medium the animal gives off a very bright, steady light for a long period, finally ceasing when it dies in its unusual surroundings. Ether and alcohol were applied by Polimanti and resulted in a very intensive lighting, which ceased at the end of from fifteen to twenty-five minutes. Whether this cessation was due to a narcotization of the central nervous system or to a more direct action on the nerve-endings or the light-cells themselves was not determined. When sulphuric acid in weak solutions was applied the animal died without giving off any light at all. We know that the light-processes will not take place in acid media, so it would appear that this acid quickly reached the light-cells and thus prevented the reaction. Further chemical experimentation could be profitably employed.

Mechanical stimulation was studied by Polimanti. He found that slight shocks, as rapping on the glass side of the aquarium, were enough to get a response by lighting; also, currents of water, produced by stirring when the animal was poked by a fine glass rod, caused it to light, but it was possible, if the action was gentle enough, to gently stroke its surfaces with the rod when no light appeared. Bubbles of air rising against it caused it to illuminate, and the presence of these bubbles in its cavities also did the same, although it reduced its sensitivity to other stimuli. The spread of the lighting from a point that had been mechanically stimulated was interesting. Polimanti found three cases: (1) If an animal was stimulated mechanically on one pole the light appeared first there, then on the opposite end or pole, and finally on the entire animal; (2) or the light spread out in bands like avalanches on the side of a mountain; (3) or the light appeared in a number of detached individuals and then in others until the whole colony lighted.

When the stimulation was applied to some middle point, much the same result was obtained. Sometimes the two ends lit first, or the light spread from the point stimulated; or it came, as in case three above, by detached points that increased in number until the whole animal glowed. Polimanti reasoned that a common nerve communication exists between the entire number of individuals in the colony, and that this communication acted in a

manner that could be compared to the nervous correlation of a single organism.

The animals were then stimulated with an induction stream of electricity through platinum points. This gave results which much resembled the mechanical stimuli, except that it was modified by the distance that the actual stimulation extended into the tissues of the colony. Of most interest, however, were Polimanti's experiments with light as a stimulus. He used a small electric lamp of 32 candle-power and found that fresh, vigorous animals would respond to a flash from the light by a response of light from their own light-organs. We know at present of only one other form, the insects, where this is true, and in these it appears to be a mating adaptation. With weaker light-power it was hardly possible to get a definite response.

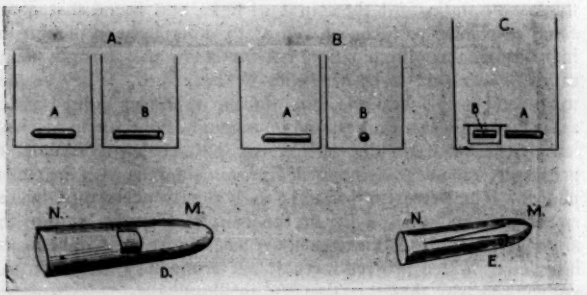
The light appeared on the colony in almost the same way as with mechanical stimulation. It might appear first at both poles and spread over the entire surface, or first at the surface and then deeper in the body. This latter condition probably means that the brighter glow brought out the inner tissues and organs, or it might mean that the adult individuals first lighted (their organs being farthest from the centre) and then the embryos which are near the inner surface of the cylinder. At times the animal failed to answer the light-stimulus, showing a varying sensitivity. We can thus see that the light-stimulation of the whole colony may result from the flash of one of its members or from the lighting of the members of another adjacent colony, or, in some cases, from the lighting of a totally different form, as a medusa or fish. This light-response was dependent upon a natural temperature and was confined to much narrower limits than in most other animals.

Burghause studied the light-emission in *Pyrosoma gigantum*. He found that the luminous organ-cells would not stain with Sudan III or osmic acid, thus demonstrating the absence of any fats. He failed to find the luciferine-luciferase reaction of Dubois, and even disclaimed the direct oxidation theory, because of his experiments with chloral hydrate and cyanogen compounds. He found the light confined to the light-organ, the ovary (eggs), and the buds and embryos. None was seen in the testis. He failed to find the varying light of several tints as described by

Peron, and ascribes it to pigments or foreign substances which might appear in the degenerating colony. All the light that he observed was of the greenish-blue color so characteristic of most luminous organisms. Also, he disagreed with Panceri and Polimanti as to the action of alcohol. When applied in strong concentrations the light was strongly shown at once. When gradually added in small quantities, however, it resulted in a narcotization under which it was impossible to get a light-response to any stimulation.

Burghause's most interesting observation was that, in fresh,

FIG. 4.



Diagrams of Burghause's experiments to prove response to light. For explanations see text. (After Burghause.)

vigorous colonies that were under normal temperature and in good sea-water, the light of one individual of the colony was answered by the lighting of those in its nearer neighborhood. He followed up this observation with careful experiments and drew a diagram (Fig. 4 in this article) to illustrate his results. In order to avoid stimulating the second colony (*b*) by accidental currents when the primary mechanical stimulus was applied to the first colony (*a*), the two were placed in separate jars or, as is seen in experiment (C), (*b*) was placed in a small dish in the same jar and covered with a glass plate to prevent disturbing it by currents produced when working with (*a*).

In the first experiment (A) the colony (*a*) was caused to

light. Shortly after it had done so the second colony (*b*) was seen to light first on the end nearest (*a*) and on those individuals which projected farthest out from the surface. The light then spread out over the entire colony. In experiment (B) (*a*) was stimulated and (*b*), whose longitudinal axis was now placed at right angles to that of (*a*), illuminated first on the side that was presented to (*a*) and then all over its surface. The strength of the reaction and its promptness was in a ratio to the nearness of the two colonies.

Burghause then tried the light of other animals; he used the ctenophores *Beroe ovata* and *Cestus veneris*, the siphonophores *Hippopodius luteus* and *Praya maxima*, as well as the Italian firefly *Luciola italica*, for the source of light, and found that *Pyrosoma* responded to them as well as to other light, although the intensity of their illumination fell far below the strength of 32 candle-power said to be necessary by Polimanti. They seemed to respond to this weaker animal light or even to a lighted match after they had ceased to respond on account of fatigue to mechanical or electrical stimuli. Bright daylight seemed to inhibit the process to some degree, in which *Pyrosoma* agrees with the ctenophores. The perception of light is evidently performed by the small pigmented organ lying on the main ganglion or brain of the animal. Since this is more easily reached by rays of light in the individuals which project farthest out from the colony, we can understand why these are the first to illuminate.

We can understand from the preceding accounts how the light may have some real use in the animal's life-habits. It would insure the closer approach of colonies that found themselves in the neighborhood of each other and consequently might insure the crossing of strains in their breeding. On the other hand, it must at times work against them by showing them to their enemies. The writer was told by Dr. L. R. Cary and others who had been studying marine animals in Bermuda that *Pyrosoma* is eaten by several large fishes of the grouper family in the deeper waters off that island. When these fishes were caught their stomachs were filled with large numbers of the colonies, presumably caught at night, as they had been partly digested when the fish were taken early in the morning. Polimanti knew this fact in Naples, and to test it he threw illuminated bits of *Pyrosoma*

colonies into the fish-tanks and they were promptly eaten by the fishes. The pieces of illuminated flesh were also eagerly sought by crabs and other animals, which fought and sought to steal them from the fish that had already secured them.

A number of other Tunicates than the *Pyrosomas* have been observed to give light, among which may be mentioned: *Cyclosalpa pinnata, Salpa democratica, S. maxima* (appendiculata), *S. micronata, S. polycratica, S. cylindrical, S. socia, S. horneri, S. truncata, S. caudata, S. zonaria, S. tilesii, Phallusia intestinalis, Doliolum sp., Ciona intestinalis,* and *Botryllus schlosseri.* While most of these are undoubtedly accurately designated as light-bearing, the last two are very improbable cases and will doubtless prove to be lighted by some parasitic or commensal protozoa or other small organisms.

LUMINOSITY IN FISHES.

The great group of vertebrate animals shows light-production, so far as we know, only among the lowest of its five classes, the fishes. Three reports—one of a luminous porcupine from India by Morean, Schläpfer, and Thompson, in which the blood is said to be luminous; another by hearsay of many nonscientific observers that some herons and cranes show luminous patches under the wings; and a third by Brandes, Dobbs, Knaur, Killerman, Lindner, Purdy, Rey, de Sibour, Ternier, and Chun—have suggested that various owls and nest-young of certain finches have shown that the light is in each case either a delusion or that, if actually seen, it was an artifact or that it was due to the presence of luminous bacteria or fungi. Some of these reports still merit further investigation that will either prove or disprove them.

Of the light-producing power of many fishes, however, we can have no doubt, and the function is found among thousands of species—some selachian fishes and a more numerous assemblage of teleost fishes.

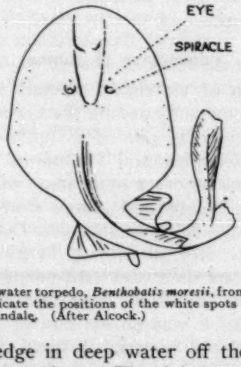
A current lay opinion on the subject ascribes all the luminous forms to those fishes which live in the abysmal depths of the ocean. While the greater number of them are so found, there are yet many others that live a pelagic life on or near the surface, and a still smaller number that lurk about the shores under stones or buried in mud or sand. Some spend most of their life

in deeper waters and come on the coast to breed at certain seasons. All the luminous forms are confined to salt water.

Selachian Fishes.

These fishes present comparatively few light-bearing members. No skate or sting-ray has been found possessing light-organs. Of the torpedoes or electric rays one species has been reported, by word of mouth, by Dr. N. Annandale, of the Indian Museum at Bombay, and in his book on Indian seas, by Dr. Alfred William Alcock, as having a series of luminous spots on the outer edge of its disk. This fish is *Benthobatis moresii*,

FIG. 5.



Outline sketch of deep-water torpedo, *Benthobatis moresii*, from the Indian Ocean. The dots on the edge of the disk indicate the positions of the white spots that are said to be luminous organs by Alcock and Annandale. (After Alcock.)

taken with the dredge in deep water off the Travancore coast, in water 430 fathoms deep. The fish has no eyes, and is the only animal so far known to possess both the power of producing light and the power of giving an electric shock. Fig. 5 shows a rough sketch of this form by Doctor Alcock. We have no knowledge of the structure of its luminous organs as yet.

The best-known group of Selachians are the sharks, and one order of these fish, the Cyclospondyli, have several members that show a very beautiful light. One of these, *Spinax niger*, is well known for its bright light, and is very common in deep tropical waters. The writer has specimens from Japan, and has seen it caught in the Mediterranean Sea at Naples, Italy.

Several other allied, light-bearing forms are known. *Squalus fulgens and Leius ferox* have been reported to be luminous by Kuer in 1865. Rudolf Burkhardt examined a number of species of "deep-water dogfish" or "black dogfish" from Naples. He was given the opportunity of seeing them alive by Dr. Lo Bianco, of the Aquarium, and mentions, as luminous, *Læmargus rostratus, L. borealis, L. brevipinnis, Spinax pusillus, Sp. niger, Sp. granulosus, Enproctomicrus labordii, Centroscyllium granulosum, C. fabricii,* and *Paracentrosyllium ornatum.*

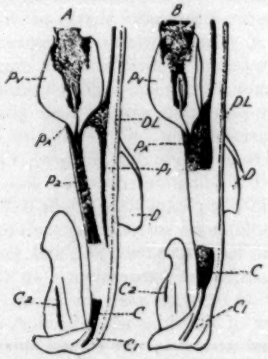
Dr. H. Oshima, of the Imperial University of Tokyo, has studied two interesting deep-water sharks of this group, *Etmopterus lucifera* and *E. frontimaculatus.* These two forms are very much alike, and, in regard to their luminous organs, almost identical, the only difference lying in a slightly varied arrangement of the numerous light-producing spots in their groups on the skin. Fig. 6 shows this arrangement, and we can also see that it closely resembles the pattern as seen in *Spinax niger.* Oshima's excellent description of their distribution reads as follows: ". . . In both species the punctate photophores are densely clustered in the following parts: small areas surrounding the nostrils, the ventral margin of the orbit, bases of paired fins, and, lastly, the postanal and caudal areas, with their extensions. In these areas there are to be counted as many as sixty or seventy photophores in a square millimetre of the skin, while in most other parts their number in an equal area does not exceed thirty or forty, and in still other parts where they are most scattered it sinks to ten or thereabout.

In these two fishes the light-organs appear as spots of a pearly lustre, and they can be easily counted and their distribution understood in the fresh specimen. In alcoholic and formalin specimens it is not so easy to see them, and they have lost their shining appearance, which is not due to their own light, but to daylight reflected from some internal surface. Under a low magnification, Oshima tells us, each organ is seen to be composed of a number of polygonal elements of a pearly lustre clustered together to form a rounded area and surrounded by a black ring of thickly accumulated pigment. In the adult specimen the smaller or punctate photophores are 0.10 to 0.15 mm. in diameter, while larger linear photophores are about 0.10 to 0.20 mm. wide and 0.30 to 1.35 mm. long. The linear photo-

phores may be regarded as a series of punctate organs merged into one row.

Fig. 7 shows a section of one of the punctate organs taken through its vertical axis at its centre. Only certain cells of the organ appear here—the lens-cells (*L*) and the pigment-cells. The description of the light-cells and other structures of the similar organ of *Spinax niger* on a succeeding page will apply to this case also.

FIG. 6.



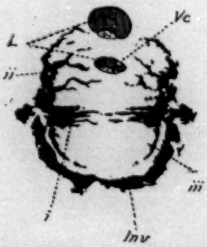
Posterior regions of the bodies of the deep-water luminous sharks, *Etmopterus lucifera* and *E. frontimaculatus*, to show the regions occupied by the light spots. These light-bearing areas are stippled in black. (After Oshima.)

Fig. 7 is drawn principally to show the form and discuss the probable use of the pigment-cells. In it we can note three kinds. Owing to the fact that no nuclei are seen and the cell outlines, where they touch, are invisible, we must explain that there are at least 10 or 12 separate pigment-cells represented in the black mass in the figure. The first sort are those below, and form a cup-shaped lower boundary of the proximal end of the organ (*INV*). This has been called the involucre of the organ. The light-cells rest in this cup, and it acts as a back-stop for internally directed rays and also possibly a reflector. Reaching inward from the rim of this are another series which may be termed the iris-cells. In the subsequent figure (Fig. 10) of the

organ of *Spinax niger* this iris is represented as closed by the extension of these cells. We know that they do so move or that their pigment moves by streaming movements through the cytoplasm to get the same effect. The last of these pigment-cells are called by Oshima the "internal and external process" cells, and they are marked *ii* and *iii* in Fig. 7. Their exact meaning is difficult to determine, but they seem, especially the external processes, to be used to shade or direct the light toward the lens-cells.

Oshima found that the light was shown only on stimulation. When confined in an aquarium the fish swam about, but never lighted until seized and rubbed on the light-areas. The luminosity

FIG. 7.



Vertical section through the long axis of one of the punctate light-organs of *Etmopterus*. *l*, lens-cells; *ins*, cup-shaped mass of reflector pigment-cells; *i*, iris pigment-cells; *ii*, external projecting pigment-cells; *iii*, internal projecting pigment cells. (After Oshima.)

was pale (possibly owing to the capture and fatigue of the fish), and appeared slowly after some minutes. The light was local on the rubbed parts, and the writer agrees with Oshima that the stimulation does not get to the organ by means of nerves from the central nervous system, but that it is a direct result of the manipulation of the pigmented iris-cells. Possibly some more or less local plexus of sympathetic nerves has something to do with the matter. We must further learn if the light is more or less continuously produced by the light-cells and is only shown or hidden by the iris-cells.

It is to L. Johann that we owe the best study and description of this power in *Spinax niger* from Japan. This little shark is abundant in deep water in many seas. It is not more than two

feet long and lives on a muddy bottom, where it feeds on small animals of all kinds. The fishermen of Japan and of Naples capture it on trawl lines baited with fish, squid, or other animal bait, and, in spite of the depth from which it is drawn, it is usually alive and can be placed in a tub of sea-water, where it swims about and, when stimulated by handling or otherwise, shows its bright bluish-green glow from many parts of the body.

Like most sharks the skin is covered by spiny points that give the rough feeling of shagreen. In this fish the color is

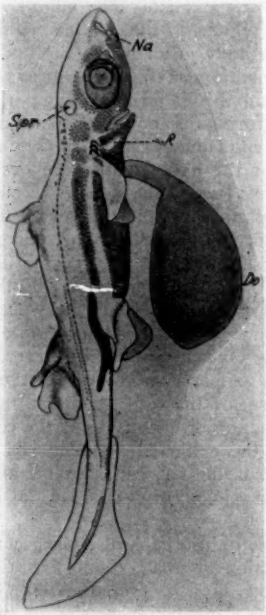
FIG. 8.

Drawing of two specimens of the deep-water shark, *Spinax niger*, with the light-areas in operation. (Drawn by Bruce Horsfall after descriptions by Johann, Beer, and the writer.)

very dark on the back, shading off to a brown on the ventral side. Cutting in on this brown are a number of splashes, stripes, and bands of almost black that take up a large portion of the under side of the head and belly in a characteristic pattern that is much the same in all specimens. When the living fish is stimulated in the dark these black areas give off a bright blue-green glow of the usual type found in light-giving organisms (see Fig. 8). The amount of light is in proportion to the freshness and vitality of the animal, and in good specimens is very bright.

The light does not shine all the time in captured specimens, and, presumably, not all the time in the animal when in its habitat. Of this latter point we are unable to judge, owing to the fact that the fishes live at so great a depth. It probably shines continually over long periods, however.

FIG. 9.



Line drawing of an embryo of *Spinax niger*, on which the grouping of the light-organs is shown by dots. (After Johann.)

When the fresh fish is examined with the naked eye in daylight or with a hand lens, one sees a large number of tiny black points very slightly raised from the skin. These occupy the dark areas before mentioned. Instead of following Johann's

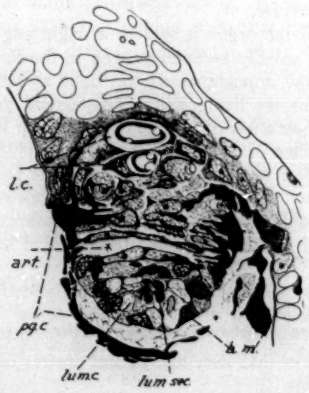
minute and accurate description of this distribution of these points (the light-organs), we will exhibit one of his figures of a young fish (see Fig. 9) on which are indicated by dotted areas the numerous patches of light-organs in the integument.

Johann further studied the microscopic structure of these organs and made out the chief points in their structure. Later Dahlgren and Kepner made a more careful study, and we will draw on this for our account. The minute organ is composed solely of modified regions of the stratified epithelium that covers the surface of the body in all fishes, the underlying connective tissues taking almost no part in its structure. In other numerous regions on the skin this same epithelium, in coöperation with mesodermal core, forms the tooth-like spines or scales. All pigment-cells in the epithelium—and they play an important part in the structure of the light-organs—are derived from certain amœboid, connective-tissue cells which secrete granules of melanin in their cytoplasm, as well as motor elements, and continue to possess the ability to move their melanin granules in such a way as to modify the light. It is probable that during growth and development the cytoplasmic bodies of these cells perform slow amœboid movements that bring them out of the mesoderm into the epithelium into such positions as we find them in the adult light-organs. Once in position, however, their chief movement is probably a temporary movement of the pigment granules inside the cytoplasm of the cells, in such a manner as to cause an apparent contraction or expansion of the cell, such as Spaeth has described for the epithelial pigment-cells of *Fundulus* and other teleosts. Thus the fish can shut off all or a part of its light. We need physiological studies on the lighting power of this animal.

All of the single light-organs of *Spinax* consist of a thickening and differentiation of small, round localities of its stratified epithelium. Sections show us (see Fig. 10) that this thickening is accommodated by a greater depression of the basement membrane at that point and a lesser raising of the outer surface of the body. The basal layer of cells is continued into the depressed cup of the basement membrane, with some interruption at the sides by the invading pigment-cells. On the bottom of the cup-like depression of the basal membrane a group of basal epithelial cells are differentiated to form the light-cells. Each

one is elongate, has a wider base containing the large nucleus, and a distal end, somewhat narrowed by its position, in the tip of which is placed a single large granule of photogenin, the light-producing proteid. Owing to the concave surface on which these cells rest their tips come together in a spot of comparatively small area, and the granules of light-producing material thus occupy a small, definite area. Above the light-cells are found a few thin, laminated epithelial cells which appear to grow out from the sides of the cup and to be in touch with these sides from which they appear to grow.

FIG. 10.



Section of a single light-organ of *Spinax niger* through its long axis. *l. c.*, lens-cells; *art*, artifact; *pg. c.*, pigment-cells: *lum. c.*, luminous cells. (After Dahlgren and Kepner.)

Above them and apparently formed by their progressive proliferation are some thicker cells whose cytoplasmic bodies are filled with vacuoles. They seem to grade directly into a few larger cells on the top of the mass, in whose cytoplasm, instead of vacuoles, we find large single bodies of a depressed-oval shape. Their outer surface is formed by a thickened shell, inside of which appears a coagulum not shown in the figure. They are said by Johann to be transparent, refractive, and to constitute a group of irregular lenses to concentrate the light. Their nuclei are difficult to see, being flattened out in a side or corner of the

cell. There are present in the average light-organ about a dozen light-cells and four or five lenses. The generalized outer layer of the stratified epithelium passes unbroken over the entire light-organ and raises some question as to the manner of its renewal. It undoubtedly is renewed by some of the laminated cells which pass through the vacuolated stage. It is possible, of course, that this does not happen and that they come entirely from the undifferentiated epithelium on each side of the organ. The latter hypothesis would relieve us of the problem of the fate of the lens-cells: whether they were permanent structures or if they slowly passed into the outer layer, to be cast off when they arrived at the surface.

The axis of the organ is seldom at right-angles to the body surface, and is usually inclined as seen in the figure. We have no record of the appearance of the light as seen with a low-powered lens in the living fish. This would give us an idea of the actual operation of the lens bodies; the light would appear at a number of quite different points if their refraction was good, while if not it would seem to come from duller spots of wider extent. The use of the function can only be guessed at. It is probably not used as a mating adaptation. In such a case it would be more concentrated in form and under more exact control.

As a means of illuminating the bottom and thereby showing the creature its prey it might very well serve. It would also do as a characteristic color marking to be used in the same way that fishes in shallower and lighter waters use their reflecting color patterns.

ADDRESS TO THE GRADUATING CLASS, THE FRANKLIN INSTITUTE, SCHOOL OF MECHANIC ARTS.*

BY

LOUIS EDWARD LEVY,

Vice-President of the Institute.

It is customary, when a class of students is about to be graduated from an institution of learning and its members are leaving to find their places in the world outside, for a speaker to address to the graduates some considerations of the purpose of their studies and some words to remind them that their efforts thus far have been only a preparation for the more strenuous tasks before them, when the knowledge they have acquired from teachers and from books is to be put to use in practical life and their mastery of their subject is to be adjudged, not in the estimates of teachers at the close of school terms, but tested by the value of their service every day, and in examinations more rigorous than any they had gone through in their school days. But the graduation of students from the night schools of the Franklin Institute presents conditions materially different from those which mark a similar occasion in the case of students who have for years been spending all their time in school or college and have thus, as yet, been students only. You members of this present graduating class, and, for that matter, you undergraduates as well, have not to be admonished of what you must expect to deal with in the workday world outside, for all of you are already active in that world and have here been devoting hours, after your daily tasks were done, in an earnest effort to more thoroughly equip yourselves for the work which you were yet to do.

You have here obtained a better understanding of the nature of that work and a fuller knowledge of the ways and means of accomplishing it. You have here learned the principles which are to be applied in your undertaking and have thereby gained a broader view of its meaning and a deeper insight into its purpose. As compared with students who pursue their courses under the seemingly more favorable conditions of uninterrupted study, you have had a great and valuable advantage in learning the science

* Delivered at the closing exercises of the Ninety-third Year of the School, April 20, 1917.

of your art in the light of your daily practice of it. There is more in this than would appear at first sight, the fact being that not only do the lessons thus learned become clearer to the learner, but also that his everyday experiences are in turn enlightened by his learning.

A course of education which adds to practical work a study of the principles on which its practice is based may well be regared as effective. And, inasmuch as your everday experience hereafter will constantly add to the practical part of your education, it is clear that to keep it effective the other part, in the form of further study, must be added by you as you go along. It is true, indeed, that our daily life is itself a process of education through the lessons of experience, and this is doubly true of those who have studied and continue to study how to better understand those lessons.

The effect of all education, as the word itself signifies, is to bring out from the inner consciousness of the learner his innate capacities of action; in short, as the saying goes, to bring out what is in him. But to bring out the best that is in him the teachings of experience alone are not enough. To that end there is need that the lessons learned through new experiences be combined with those of further study, for without that combination much that is in the learner will become useless through lack of development or worse than useless through a distorted development. It is as when a good planting, for want of cultivation, fails entirely or reaches only a stunted or defective growth. The idea suggested by Alexander Pope that "a little knowledge is a dangerous thing" but expresses in a terse formula the experience of every generation in every line of endeavor. You have doubtless already found out for yourselves that your studies here are only a beginning, and you will have to keep them up by yourselves if your mastery of your work is to keep pace with its requirements and your sense of proportion (that is to say, your judgment) is to be clarified by your experience.

It has often been remarked that the most that a school can do for its pupils is to teach them knowledge and the rules for applying it, but that the application of their knowledge to conditions which are exceptions to the rules can be learned only in the school of experience. But this is only a half-truth, the fact being that new rules are being made and old ones changed as science and the arts advance, and these advances must be kept

up with after school days and study continue to go forward with experience. You have had the advantage of pursuing both courses together during the time of your schooling here, and the combined result of your daily experiences and your nightly studies has surely been your acquirement, however, unconsciously, of a capacity for a higher quality of service than could have been attained through either course alone. In all these respects you have but followed in the footsteps of many hundreds of your forerunners for whom the night schools of The Franklin Institute have opened the way to broader fields of endeavor and to larger spheres of usefulness.

Broad as those fields already are, broader than at any time before, they are daily being widened and their scope enlarged by the constant advances of science and the development of the arts. Every new achievement in these ranges of progress opens a vista of other and often greater possibilities beyond, visions which are yet to be realized by further effort directed by just such training as you have received here. There is no field of activity that cannot be enlarged, no addition to our knowledge of Nature's ways that does not offer to the worker an invitation to apply it. The field is open and the invitation is to you.

As I look back across the fifty years and more of my active experience I am impressed with a realizing sense of the fundamental changes which have been brought about within that time in all the various fields of human activity through the revelations of science which have so largely extended our control of the forces of Nature and so greatly widened the scope of the constructive arts. These developments have changed materially the conditions of our daily life, modified greatly our attitude towards surrounding nature, altered in many ways the interrelations of men and ultimately those of nations also. And now, within the short space of your schooling here, the world of human affairs has been going through a violent struggle in the process of its adjustment to these all-pervading changes, like as when an earthquake shakes the land in the course of adjustment to accumulated changes beneath the surface.

It is a struggle in which the course of civilization seems brought to a standstill and in which all the gains of science that make for progress and all the achievements of the arts that signalize it are being diverted from their beneficent purposes and applied to those of ruin and destruction on a scale of unparalleled magni-

tude. Of the authors of this terrible calamity, of the historic background of the struggle and of its political complications we need not here take account. More insistent, however, upon our immediate consideration is the fact that we here in this western world, where the adjustment of the social structure to changing conditions of life proceeds without violence as occasion for adjustment arises, we here, though far removed from the arena of the struggle and yet farther from its immediate causes, have been forced to take part in it and find ourselves at war. We are forced to take up arms in defence of those ideals of righteousness and freedom which have been the inspiration of our national life from its beginning, the upholding of which has given us leadership in the march of civilization, made our country a beacon-light for all the nations, and centred in it the hopes of all who yearn for righteousness and freedom throughout the world.

We are all of us called upon to stand together in this defence. We are each of us called upon to do our part in warding off the danger to our welfare and to join with all who in this great war are fighting to prevent the rule of might being made superior to the rule of right, and to put an end to the sway of force in the lands of civilization.

This great war is certain to be followed by a yet greater peace, when the disjointed remnants of the Dark Ages of Europe that yet clutter the roadway of the world's progress will have been swept away and the march of civilization, now so cruelly arrested, will be resumed. It is for you and such as you throughout the land to do your part in the conquering of that peace and in hastening the day when the present revel of destruction will be ended and when you and such as you will be called upon to do the work of reconstruction that is to follow.

NATIONAL RESEARCH COUNCIL.*

BASIS OF ORGANIZATION AND MEANS OF COÖPERATION WITH STATE COUNCILS OF DEFENSE.

ONE of the most striking results of the war is its demonstration of the importance of scientific research in strengthening the national defense. Soon after the opening of hostilities, England and France were faced with industrial and military demands soluble only in their research laboratories. Looking ahead, it was seen that the conclusion of peace would be followed by a trade war with Germany, in which no industry not perfected by scientific research could be expected to survive. As a consequence there arose through governmental action in England, France, Australia, New Zealand, and Canada a group of research organizations charged with the mobilization of scientific men and laboratories for the study of military and industrial problems. The value of their contributions to military practice has been recognized by the French Minister of War and by Sir Douglas Haig in his reports from the front. The success of their efforts to relieve industrial distress resulting from the stoppage of exclusively German products has greatly enhanced the appreciation of scientific research by British and French manufacturers. Thus the scientific methods which lie at the basis of Germany's military and industrial strength have been effectively adopted by the Governments and peoples of the Entente.

In April, 1916, soon after the attack on the *Sussex* and our consequent demands for the cessation of submarine warfare had developed a critical situation with Germany, the President requested the National Academy of Sciences to organize the scientific resources of the United States in the interest of national security and welfare. The request of the President called for immediate and vigorous action. He expressed the desire that the Academy should coördinate the scientific resources of the entire country and secure the coöperation of all agencies, governmental, educational, and industrial, in which research facilities are available.

* Acting as the Department of Science and Research of the Council of National Defense. Communicated by Dr. George E. Hale, Chairman.

The National Research Council, comprising the chiefs of the technical bureaus of the army and navy, the heads of government bureaus engaged in scientific research, a group of investigators representing educational institutions and research foundations, and another group including representatives of industrial and engineering research, was accordingly constituted with the active coöperation of the leading national scientific and engineering societies. The representatives of the government were appointed by the President, who promised his cordial support and the cooperation of the government departments. Subsequently (February 28, 1917) the Council of National Defense adopted the following resolution:

"*Resolved*, That the Council of National Defense, recognizing that the National Research Council, at the request of the President of the United States, has organized the scientific forces of the country in the interest of national defense and national welfare, requests that the National Research Council coöperate with it in matters pertaining to scientific research for national defense; and to this end the Council of National Defense suggests that the National Research Council appoint a committee of not more than three, at least one of whom shall be located in Washington, for the purpose of maintaining active relations with the Director of the Council of National Defense."

Since that time the National Research Council has acted as a department of the Council of National Defense, charged with the organization of scientific researches bearing on the national defense and on industries affected by the war.

WORK OF THE RESEARCH COUNCIL.

In times of peace the work of the Research Council involves the promotion of research in every department of pure and applied science. At present, however, the attention of the Council is concentrated on war problems, both military and industrial. Let us see how these are attacked.

The Military Committee consists of the Surgeon General of the Army, the Medical Director of the Navy, the Chiefs of Ordnance of the Army and Navy, the Chief Signal Officer of the Army, the Chief Naval Constructor, the Engineer-in-Chief of the Navy, and the Director of the Bureau of Mines, the Chief of the Weather Bureau, the Director of the Geological Survey, Mr. Howard Coffin of the Advisory Commission of the Council

of National Defense, the Director of the Bureau of Standards (Secretary), and the Secretary of the Smithsonian Institution (Chairman). This committee formulates most of the military problems, designating in each case an officer in one of the technical bureaus of the army or navy who is familiar with the requirements and with whom the investigator engaged in the work may keep in touch. Dr. Robert A. Millikan, vice-chairman of the Council charged with the correlation of researches bearing on the national defense, then organizes the investigation by enlisting the services of one or more men especially qualified by experience and laboratory equipment. If, as is usually advisable, several research men attack the problem simultaneously, Doctor Millikan arranges for any desired coöperation between them. Freedom of initiative is encouraged, and any attempt at hampering control or interference with the freedom of action required for successful research is carefully avoided.

The above remarks relate more particularly to physical research, though Doctor Millikan's field of activity embraces a much wider range. Associated with him in Washington are Doctor Bogert, chairman of the Chemistry Committee; Doctor Vaughan, chairman of the Committee on Medicine and Hygiene; Doctor Durand, Vice-chairman of the Engineering Committee, and Doctor Mendenhall, Vice-chairman of the Physics Committee. These gentlemen, as well as the chairmen of the other committees of the Research Council, are constantly engaged in organizing researches in their respective fields, in coöperation with the Military Committee and with Doctor Millikan. In this way a most helpful and inspiring association of our individual investigators, our universities, our industries, and the various branches of our Federal Government, is being brought about—a coöperation which is of the utmost value to any country and which is vital to it in time of war.

It may be of interest here to give some illustrations of the ways in which the various committees are contributing to the national defense.

Mathematics (Dr. E. H. Moore, chairman) and

Astronomy (Dr. E. C. Pickering, chairman).

Hydrodynamical investigations bearing on ship design and improvement of aircraft. Statistical studies and computations

required in any field. Optical devices for lookouts, to facilitate the detection of the periscopes of submarines.

Physics (Dr. R. A. Millikan, chairman).

Exhaustive study of devices for dealing with the problems of submarine warfare; range-finders of various types; devices for detecting invisible aircraft and sapping parties; improvements in wireless apparatus and other instruments used with aircraft; military photography.

Chemistry (Dr. Marston T. Bogert, chairman).

Generation, detection, and absorption of hydrogen, and problems incidental thereto; absorption of other gases, particularly noxious ones; fire extinguishers; prevention of corrosion and electrolytic action on the hulls of vessels; non-corrosive metals and alloys for a great variety of uses; balloon fabrics; fabrics for army slickers; bacteriological and biological stains; synthetic drugs; special reagents for investigators; new explosives; new sources of important products; utilization of wastes and by-products.

Botany (Dr. J. M. Coulter, chairman).

Organization of a botanical raw products clearing-house, to aid manufacturers needing raw products of a botanical nature, such as gums, oils, resins, fibres, wood, etc., to find either new geographical sources or new specific sources.

Geography (Dr. W. M. Davis, chairman).

Special maps for military purposes; instructions for the use of topographic maps; handbooks on military areas; physiographic features of the United States.

Geology (Dr. J. M. Clarke, chairman).

Camp sites; finding of water supply; materials for road building; topographic structure of military areas; supply of necessary minerals.

Medicine and Hygiene (Dr. Victor C. Vaughan, chairman) and *Physiology* (Dr. Walter B. Cannon, chairman).

Antitoxins and serums for diphtheria, tetanus, pneumonia, dysentery, and meningitis; intradermal method of vaccinating for smallpox; polyvalent vaccines for typhoid fever; sterilization of

drinking water; toxicity of preserved foods; soldiers' clothing and blankets; infected wounds; shock; fatigue; occupational diseases, with special reference to munition workers; protection of the ear from high explosives; instruction of army and navy surgeons in the Carrel method of antiseptic surgery.

Anthropology (Dr. W. H. Holmes, chairman) and

Anatomy (Dr. H. H. Donaldson, chairman).

Physical and hygienic requirements of recruits for the army and navy; language requirements; condition of teeth; abnormalities; minimum height and weight; standardization of measurements; data and materials for scientific research.

Psychology (Dr. Robert M. Yerkes, chairman).

Organization of psychological tests for use in recruiting, to eliminate mental defectives and nervous types; selection of recruits especially adapted for aviation and other difficult tasks; study and treatment of returned soldiers, nervously or mentally affected; aid in re-education of partially incapacitated men; aid in deciding government liability and award of pensions.

Engineering (Mr. Gano Dunn, chairman; Dr. Durand, vice-chairman).

This committee, which will organize research in the various branches of engineering, has just been established with the co-operation of the national engineering societies.

In addition to the above general committees, the Research Council has a number of special committees dealing with important problems.

Nitrate Supply (Dr. Arthur A. Noyes, chairman).

This committee, which was appointed at the request of the Secretary of War, to consider the process to be used by the government in its plant for producing nitrates for explosives and fertilizers, has submitted a full report.

Noxious Gases (Mr. Van H. Manning, chairman).

This committee is making an exhaustive study of noxious gases used in warfare, and the various methods of protection against them.

Food (Dr. Alonzo Taylor, chairman).

This committee is working in coöperation with Mr. Hoover and with the Department of Agriculture.

An extensive investigation of the toxicity of preserved foods is also being conducted by Doctor Rosenau in consultation with an advisory committee named by the Research Council.

Optical Glass (Dr. Robert A. Millikan, chairman).

Through the coöperation of the Bureau of Standards and the Geophysical Laboratory of the Carnegie Institution of Washington with glass manufacturers, the problem of supplying optical glass for military purposes is well advanced toward solution.

Foreign Service Committee (Dr. Joseph S. Ames, chairman).

The first step in any work of research is to learn what has already been accomplished in the same field. Great progress has been made abroad since the beginning of the war by the scientific investigators of the allied countries. A committee has accordingly been sent to Europe to report from the front on scientific matters of every kind and to arrange for coöperation in the study of questions still underlying military and industrial problems. This committee includes two physicists, two chemists, one metallurgist, and two representatives of medicine and hygiene.

Committees of the Research Council not immediately engaged on national defense questions are those on the Promotion of Industrial Research (Dr. J. J. Carty, chairman) and on Zoology (Dr. Edwin G. Conklin, chairman). The Agriculture Committee (Dr. Raymond Pearl, chairman) is coöperating with the Department of Agriculture in the organization of research and the mobilization of the agricultural resources of the country.

CENSUS OF RESEARCH.

A national census of the research facilities of government bureaus, educational institutions, research foundations, and industrial research laboratories is being taken by the Research Council. The forms from educational institutions, which are coming in rapidly, contain much valuable information bearing on the solution of defense problems. Forms for other institutions are now being sent out.

The Committee on Research in Educational Institutions has

recommended the formation of Research Committees in universities, colleges, schools of technology, and other educational institutions where research is conducted. The Research Committees already established by a large number of institutions in response to this request serve as local organizations which work in coöperation with the Research Council.

COÖPERATION WITH STATE COUNCILS OF DEFENSE.

The organization of the National Research Council is based upon the principle of broad and effective coöperation between the numerous research agencies of the United States and those of the allied countries. The Council is in reality a federation of research laboratories, working together toward a common end. At present its chief purpose is to assist in winning the war, both by the perfection of military devices and by the solution of industrial problems which the war has occasioned. But in the future, as already stated, it will devote its attention to the promotion of research in all branches of pure and applied science.

The organization of researches bearing on the national defense frequently involves the coöperative effort of many investigators residing in different states. Sometimes the joint action of an entire university laboratory, provided for through the assistance of the Research Council of the university in question, is essential to success. We have several researches in hand in which entire laboratories are taking part. More commonly, however, individual investigators known to be especially qualified are enlisted by the National Research Council from widely scattered institutions.

Such is the mode of procedure necessarily followed in the study of national problems. Local questions are constantly arising, however, which can be best solved through the efforts of local investigators familiar with the particular industries or resources involved, acting in coöperation with a national body in touch with researches in progress at home and abroad.

We accordingly suggest that the representatives of science and engineering, or the Research Committees appointed by State Councils of Defense for the purpose of promoting through scientific investigations the industrial and agricultural development of the several states, arrange for close coöperation with the National Research Council. In this way the research activities of the states may be coördinated with one another and with

those of the national government, and the information secured by the National Research Council and by the separate state organizations may be rendered available for all.

Communications regarding the Research Council may be addressed to the Chairman at the Munsey Building, Washington, D. C.

WASHINGTON, May 1, 1917.

Speed Governors for Motor Trucks. ANON. (*Municipal Engineering*, vol. lii, No. 4, p. 187, April, 1917.)—Excessive speed has always been one of the drawbacks in the use of the modern motor car, and the attempt has been made in the past to regulate speed by legislation, imposing fines and even imprisonment for violations. The principal practical trouble has been with the driver. The want of dependability on the part of the driver was strikingly illustrated in the results of an investigation made by French artillery officers early in the present war. It was found that the maximum speed at which certain pieces of heavy artillery could be moved with safety on steel tires was eleven and one-half miles per hour. On a test run of two hundred miles over normal roads at an average of thirteen miles per hour, the gun was returned with practically nothing complete, and as a useful weapon the gun had been completely ruined. Orders were at once issued limiting the speed of these guns, yet it was found that the drivers of the trucks trailing them could not be relied upon to keep within the prescribed maximum, and guns were repeatedly found to have been seriously injured through hurried, though short, movements of position. The remedy adopted was the governor equipment of the trucks.

One of the taxicab companies of New York City is now considering the governor equipping of all its new cabs and limiting the speed to the prescribed maximum of the speed regulations of the city. Motor trucks, more particularly the heavier varieties, complicate the problem so far as road legislation is concerned, because comparatively slow speeds for heavy trucks destroy the roads much more rapidly than much higher speeds on pneumatic tires. The importance of the speed factor in road wear is perhaps not generally appreciated. Highway engineers say that road shock, or the hammer effect of the vehicle upon the road, increases as the weight times the speed, assuming otherwise like conditions. Heavy loads on narrow or hard tires propelled at high speeds develop strains for which the average road is not designed and cannot successfully carry. It would seem, therefore, that automatic speed controls, particularly for commercial vehicles, are becoming necessary, whether from the point of view of public safety, the protection of the roads, or the protection of the vehicles themselves.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE EFFUSION METHOD OF DETERMINING GAS DENSITY.[1]

By Junius David Edwards.

[ABSTRACT.]

THE effusion method of determining gas density, which is based upon the fact that the times required for the escape of equal volumes of two gases under the same pressure through the same small orifice are approximately proportional to the square roots of the densities of the gases, was investigated in order to determine the accuracy of the method and its sources of error. In coöperation with a number of men employing this method in the natural gas industry, a series of experiments was made, using their apparatus under field conditions. It was found that results in error by more than 10 per cent. were not unusual.

The theory of the effusion process was studied in order to determine the influence of the numerous variables affecting the apparent specific gravity. The effect of differences in physical properties upon the relative rates of effusion of air and hydrogen, argon, methane, and carbon dioxide at different pressures was determined. A more detailed treatment of the theory in the light of these results will be given in another paper. The facts observed in this study, together with the observations made on the effect of the effusion pressure, the confining medium, and the shape and size of the orifice, have been used in determining the most favorable conditions of operation for this method.

It is very important that the orifice be of the proper size and shape. Recommendations have been made as to the most suitable type and form of apparatus for use and specifications given to guide in the construction of the orifice.

* Communicated by the Director.

[1] Technologic Paper No. 94.

It has been shown that the apparent specific gravity as determined by this method can be varied within rather wide limits by changing the conditions. However, by the observance of certain precautions in the construction and use of apparatus, it is possible to secure results accurate to about 2 per cent. The greatest precision is obtained where the physical properties of the gas tested show the least difference from those of air. Some further increase in accuracy, and particularly in reliability, can be gained by standardizing the apparatus as recommended.

THE EMISSIVITY OF STRAIGHT AND HELICAL FILAMENTS OF TUNGSTEN.*

By W. W. Coblentz.

IN the present investigation data are given on the radiation from the inside and the outside of the turn of a helically wound tungsten filament in an atmosphere of nitrogen.

The intensity of the radiation from within the turn of the helix is from 90 to 100 per cent. greater than from a similar area on the outside of the turn. This is accounted for on the basis of multiple reflection within the helix. This modifies the quality of the light so that it is redder than the light from the outside of the turn.

The observed infra-red measurements on the radiation from within the helix and the computed values (obtained on the basis of multiple reflection and the reflectivity of tungsten) are in close agreement, which is further evidence that the phenomenon is the result of multiple reflection.

Tests were made with a Nicol prism, which showed that the light from within the filament is highly polarized, indicating that the quality of the light is quite different from that of a black body. The infra-red energy measurements also indicate that the quality of the radiation emitted differs from that of a black body.

Computations of the radiation constant of tungsten indicate, as found in previous investigations, that the Wien equation is not applicable to the radiation from tungsten.

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* Scientific Paper No. 300.

There is no indication that the temperature within the helix is higher than on the outside of the turn. A difference in temperature of 200° would be required to account for the observed difference in brightness of 90 per cent.; whereas pyrometric, thermal conductivity, and other measurements place this temperature difference at less than 5°.

Although the quality of the radiation has been modified by multiple reflection within the helix, it is not sufficiently similar to that of black-body radiation to permit its use in exact temperature measurements by sighting an optical pyrometer within the turns of the helix.

AN ANEROID CALORIMETER FOR SPECIFIC AND LATENT HEATS.*

By Nathan S. Osborne.

[ABSTRACT.]

THE principle of the unstirred or "aneroid" type of calorimeter has been embodied in an instrument especially designed for determinations of the specific heat and latent heat of several substances in general use as refrigerating media.

Heat developed electrically in a coil located in the central axis of the cylindrical shell comprising the calorimeter is distributed by conduction to the calorimeter and contents, whose initial and final temperatures when in thermal equilibrium are measured by a platinum resistance thermometer.

Heat from other sources is excluded by enveloping the calorimeter with a metal jacket separated from it by an air space and keeping this jacket during measurements at the same temperature as the calorimeter surface, using multiple thermocouples to indicate this equality.

The calorimeter is adapted for use between −50° C. and +50° C. and for pressures up to 70 atmospheres in experiments where the measured heat added is used either to change the temperature of the contents or to evaporate a portion of the contents withdrawn as superheated vapor; in the first case the

* Scientific Paper No. 301.

specific heat and in the second the latent heat of vaporization being obtained when proper corrections are made. Such experiments are described in separate papers, this paper being devoted to the description of the instrument and its calibration.

Several features to which special attention has been given are:

1. Refinements to reduce errors in the evaluation of thermal leakage. These refinements include the following details:

(*a*) Location of the heater in the central axis of the calorimeter so that abrupt thermal irregularities produced by the heat developed therein may be subdued before affecting the surface.

(*b*) Distribution of metal connections between calorimeter and jacket in such a way that the lead conduction is unaffected by inequalities in the surface temperature of the calorimeter.

(*c*) Protection by means of superficial copper sheaths of the calorimeter surface from abrupt variations in temperature such as may occur within during calorimetric measurements.

(*d*) Method of indicating relative mean surface temperatures of calorimeter and jacket by means of multiple integrating thermocouples, which permits the evaluation of, and usually the annulment of, the thermal leakage.

2. Provision, by means of a system of radial metal vanes, for the distribution of heat throughout the contents.

3. Provision for insuring the dryness of vapor withdrawn by means of baffle plate system.

4. Installation in the calorimeter of a strain-free type of platinum resistance thermometer selected to give requisite accuracy.

5. Devices for rapid cooling of the calorimeter, consisting of a copper ring which can be moved within the jacket so as to thermally short-circuit the insulating air space and permit the escape of heat to the cooled jacket.

6. Thermo-regulated bath for keeping the temperature of the isothermal envelope or jacket always under control of the observer in order to avoid any unmeasured heat increments by thermal leakage.

Many other details are described which have a bearing on the convenience or accuracy in the use of the instrument.

The method of manipulation in making measurements of heat capacity is described and the results are given of an extended

series of observations in the temperature range from − 50° C. to + 50° C. to determine the heat capacity of the empty calorimeter.

WAVE-LENGTHS OF THE STRONGER LINES IN THE HELIUM SPECTRUM.*

By Paul W. Merrill.

[ABSTRACT.]

WAVE-LENGTHS of 21 of the stronger helium lines have been carefully measured photographically by means of the Fabry and Perot type of interferometer, using several separations. Nine of the lines were compared directly with the standard cadmium line 6438.4696A, the remaining lines being referred to these. The accuracy attained is nearly 0.001A, so that the lines will become available as convenient standards for many purposes.

The fact is well known that the separation of the effective reflecting surfaces of the interferometer usually appears to be slightly different for different colors. The possibility is noted of eliminating the effect on measured wave-lengths by taking differences of orders and of thickness from large and small interferometers.

The Kayser and Runge formula for spectral series with constants derived from three consecutive lines will not reproduce accurately even the next member of any one of the six series.

THE RELATIVE SENSIBILITY OF THE AVERAGE EYE TO LIGHT OF DIFFERENT COLORS AND SOME PRACTICAL APPLICATIONS TO RADIATION PROBLEMS.†

By W. W. Coblentz and W. B. Emerson.

[ABSTRACT.]

IN the present investigation the methods are practically the same as used by previous experimenters. In the visual measurements the spectral light was compared with a standard white light by means of a flicker photometer and also an equality-of-brightness photometer. The source of white light was a standardized vacuum tungsten lamp. A cylindrical acetylene flame was used as a source of spectral light. The distribution of energy

* Scientific Paper No. 302.

† Scientific Paper No. 303.

in the spectrum of the acetylene flame was determined with great care in view of the fact that the disagreement in previous work seemed to be due, in part, to uncertainties in radiometrically evaluating the light stimulus.

Visibility curves were obtained on 130 persons, of which number seven were known to be color-blind. The visibility curve of the average eye, using 125 observers, is wider than previously observed.

As was to be expected, the visibility curves of no two persons appear to be exactly alike. When a visibility curve does not coincide with the average there is usually a marked departure from the average visibility in a given spectral region. This gives rise to (1) wide visibility curves with the maximum shifted toward the red, *i.e.*, "red sensitive," (2) narrow curves with a sharp maximum in the green, and (3) curves with the maximum shifted toward the violet.

The data available indicate that 60 per cent. of the cases examined fall into three quite evenly divided groups (*i.e.*, 20 per cent. roughly estimated in each group) which are either (1) red sensitive, (2) blue sensitive, or (3) average. Similarly, 30 per cent. of the cases examined are quite evenly divided into three groups which fall below the average in either (1) the red, (2) in the blue, or (3) in both the red and the blue, thus giving rise to an apparently high sensibility in the green. One person in about twenty has a very wide visibility curve as compared with the average.

The point of maximum visibility is very different for different observers. The curve of average visibility, when corrected for selective transmission of the ocular media, including the yellow spot, is very symmetrical.

The complete paper gives a mathematical equation of the average visibility curve, and applications of these data to physical photometry. Further applications are given in a separate paper.

Calculations are given showing that the eye responds to light having an intensity less than 1×10^{-16} watt.

This paper gives also data on diffuse light in the spectroscope used, and a screen is described which transmits radiations proportional to the average eye.

NOTES FROM NELA RESEARCH LABORATORY.*

ON "STEREOSCOPIC" COLORS.

By M. Luckiesh.

On viewing colored objects in the same plane, such as printing in various colors in the projected image of a lantern slide, the different colors do not always appear to be in the same plane. The author has found persons who have observed this phenomenon, but has been unable to find any published data. This note describes some preliminary measurements of the magnitude of this "stereoscopic" effect. Two wooden boxes, each containing a tungsten lamp and equipped with an aperture covered with a diffusing glass, were arranged so that one was stationary and the other movable. Before the diffusing glass in one box were placed a red filter and an opaque card in which a letter X was cut. The other box was similarly fitted with a blue filter and diaphragm in which a letter E was cut. The height of the letters was 2.2 cm. and the width was 1.5 cm. In a dark room these two colored letters stood out in space, and it was possible, by moving one or the other, to make them appear in the same plane. In obtaining the data in the table the red X was moved. In most cases it was necessary to move it farther away than the blue E in order to make both appear in the same vertical plane perpendicular to the line of sight. These amounts are given in centimetres for total distances, which are given in metres. There is a general increase in these amounts with increasing total distance.

The values in the table which bear negative signs indicate that in these cases the red X had to be *nearer* the observer than the blue E in order to appear in the same plane. This complicates the explanation. Besides the data presented in the table, seven other observers have been examined at one distance and each stated that the red X appeared closer than the blue E when they actually were in the same plane. The observations represented only one series of ten settings at each distance, with the exception of the first two observers, on which two series were run.

* Communicated by the Director.

Total distance in metres	2½ cm.	4 cm.	5 cm.	6 cm.	7½ cm.
M. L.	2.8	16.0	24.6	39.8	57.7
H. K.	4.8	13.7	21.0	31.7	46.2
F. G.	1.6	5.3	7.6	5.3	12.5
P. H.	3.1	15.1	8.4	35.6	49.5
L. M.	2.6	4.5	13.4	14.4	18.3
E. K.	7.4	28.2	50.9	22.6	71.7
H. P.	5.1	2.4		23.2	17.4
L. C.	−0.4	−1.9	1.4	8.9	−2.7
G. H.	−7.4	−18.5	−34.0	−37.6	−49.7

The phenomenon is somewhat fluctuating, although by training and with standardized conditions fairly consistent results were obtained. Computations from the data by M. L. indicate that chromatic aberration in the eye could account for this phenomenon, but the negative values for the last two observers complicate this explanation. If the two letters are placed in the same plane they will not appear in the same plane, but by nearly closing the eyelids they appear to move into the same plane. Similarly when the two objects were placed so that they appeared in the same plane, on nearly closing the eyelids the red X appeared more nearly in its true position; that is, back of the blue E.

When two very small artificial pupils were placed respectively before each eye the blue E could be made to appear either behind or before the red X. It appeared to move to and fro very strikingly, as the two artificial pupils were moved laterally with respect to each other. It appears that, for those who normally see the red X behind the blue E, when the artificial pupils were moved closer together the blue E apparently moved forward and when the pupils were separated a trifle more the blue E moved backward. Through these small artificial pupils both images appeared in focus at all times, which was not true with the natural pupils. On turning the head, results somewhat similar to the foregoing were obtained.

Differences in relative brightness and shape of the colored characters seemed to influence the magnitude of the results somewhat, although the effect was never reversed. The effect could not be observed with certainty with one eye. Training in observing the phenomenon seemed to be important in obtaining consistent results, although the observers whose data are presented in the table had no experience in observing the phenomenon excepting the first observer in the list.

To explain the phenomenon with certainty much more work must be done, but there are indications that it may be explained eventually as due to the different refractive indices of the eye media for radiant energy of different wave-lengths. This may cause a displacement of the colored images which gives rise to the stereoscopic effect quite in the same manner as in ordinary vision. If this is the explanation, the differences between individuals shown in the table will likely be explained by differences in the shapes and relations of the various parts of the eye, such as curvatures, eccentricity of pupils, etc.

The Audubon (La.) Sugar School. C. E. COATES. (*The Journal of Industrial and Engineering Chemistry*, vol. 9, No. 4, p. 379, April, 1917.)—A little over a century ago, when sugar was first made from beets, the root was low in sucrose and the process gave a poor yield of an inferior grade of sugar, with almost valueless molasses. The chemist and agronomist, working together, slowly raised the sucrose content of the beet-root until it was more than doubled; the chemist and engineer, working together, slowly improved the processes until a good yield of sugar was turned out, practically pure, and both the molasses and all the other by-products became sources of profit and not of loss. In consequence the net cost of beet-sugar fell year by year until it became a serious competitor of cane-sugar, and finally it was offered at prices closely approaching the cost of cane-sugar production. The sugar planters of Louisiana, appreciating the increasing gravity of the situation, decided to meet the competition of beet-sugar by the same method that made competition possible. In the late eighties they called to Louisiana Dr. W. C. Stubbs and established, under his direction, the Sugar Experiment Station at Kenner, La., which was subsequently moved to Audubon Park, on the outskirts of New Orleans. This station was financed entirely by the planters of Louisiana. A complete sugar-house was erected on a scale large enough to give commercial results, and altogether perhaps $100,000 worth of equipment was obtained either by purchase or gift.

As soon as the work was fairly under way it became evident that there were many leaks in the sugar industry as carried on in Louisiana, and that these could be stopped by proper scientific control. But when the planters looked for chemists and engineers they were not to be obtained. Up to that time the cane-sugar industry throughout the whole world had been carried on largely by the rule of thumb. Few men scientifically trained were to be found outside of Europe. In 1890, therefore, at a meeting of

the Sugar Planters' Association, it was decided to establish, in connection with the Sugar Experiment Station, a school for the training of experts in sugar work. This was placed under the direction of Doctor Stubbs and was opened in 1891 as the Audubon Sugar School. This appears to be the first instance in America in which any industry established both laboratories for the scientific investigation of its problems and a school for the college training of men to put the theory into practice. In 1896 the school was incorporated with the Louisiana State University, preserving the name by which it had become known. In 1908 it was reorganized as a college of the university.

Mother Maps of the Country. ANON. (*U. S. Geological Survey Press Bulletin,* No. 317, April, 1917.)—When it is proposed to prepare a map for any special purpose, the first thing that should be done is to find out whether the United States Geological Survey, of the Interior Department, has not already printed a topographic map of the region. The Survey's topographic map has been called the "mother map," and it is being supplied to an ever-widening circle of industrial and scientific agencies for practical use in the study of all sorts of problems and the execution of all sorts of projects. It is especially valuable in the solution of problems that require a study of the configuration of the country. In other words the topographic map is an engineering base map that is useful for both the simplest and the most complicated engineering problems.

A recent notice in one of the industrial journals called attention to the fact that in some counties where extensive systems of road construction are being planned maps have been *prepared* to accompany the specifications and the calls for bids so as to show the location of all material supplies available and all railroad connections. The Geological Survey's topographic map is the accurate base for such a map *already prepared* and contains far more of the information desired than any map that can be specially prepared for such a purpose, except at a cost that would be absolutely prohibitive. On the Survey's base map any special data can be readily platted. On this map could be shown in considerable detail the routes of proposed highways as well as the adjoining country, together with all routes of railroad, water, and overland transportation. The contractor could thus locate his materials, determine the best means of transportation, and make his estimates with greatly increased confidence as to their accuracy.

Cities, state organizations, official boards, contractors, and others are recognizing more and more the immense practical service and value of a ready-made map which shows not only every physical feature of the area it represents, but all the works of man.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE PHOTOMICROGRAPHY OF PAPER STRUCTURE.[1]

[ABSTRACT]

In the study of the ultimate structure of paper much valuable information can be obtained by means of photomicrographs of cross-sections of the paper stock.

In the course of some recent work on the penetration of various materials into paper stocks it was found necessary to develop a technique for making sections of paper stocks as thin as 0.05 mm. The following method was adopted:

The particular type of microtome used is manufactured by the Spencer Lens Company, of Buffalo. The micrometer adjustment permits of sections from 0.001 to 0.05 mm. in thickness being made.

The paper of which a section is desired is mounted between two pieces of gelatine-coated film, ordinary kodak N. C. film being used, the gelatine being moistened to cause it to adhere to the paper. The paper held between the pieces of film is then placed between two pieces of moderately dry castile soap. This "sandwich" is then placed in the chuck of the microtome with the paper edge normal to the razor edge. The use of the gelatine is important, as it forms a firm but slightly resilient binder for the paper and prevents tearing of the surface fibres.

Sections are then cut in the usual manner and mounted on slides in Canada balsam diluted 1 to 3 in xylol.

In photographing such sections the best results are obtained by using orthochromatic plates with a yellow filter. In the present work Standard Orthonon plates were used with the Wratten "G" filter.

* Communicated by the Director.

[1] Communication No. 49 from the Research Laboratory of the Eastman Kodak Company, published in *Journal of Industrial and Engineering Chemistry*.

Pyrometers—Past, Present, and Future. R. P. BROWN, before Steel Treating Research Club. (*The Iron Trade Review*, vol. lx, No. 12, p. 671, March 22, 1917.)—So far as we know, the ancients, who baked excellent bricks and forged iron in their crude way, made use of a form of pyrometer used to-day with ever-diminishing success—the eye. The operation of the first mechanical pyrometers depended upon the difference in expansion of iron and brass. An iron tube containing a brass rod projected into a furnace, and these were mechanically connected to a multiplying movement which caused a pointer to pass around a dial. Thirty or forty years ago the Siemens copper-ball water pyrometer was quite largely used. It is still used by armor-plate manufacturers, and an accuracy within about 25° F. is usually attained.

Present-day pyrometers are based upon the change of resistance of a standardized conductor or the change of the electromotive force from a thermocouple with a change of temperature. The resistance thermometer is an exceedingly accurate one, but is hardly to be recommended for high temperature service. For measuring temperatures above 1000° F. the thermo-electric method has come to be by far the most widely used. Experience has taught that for temperatures up to 200° F. a thermocouple of antimony and bismuth is best. For temperatures to 1000° F. a satisfactory thermocouple consists of one wire of iron, the other 60 per cent. nickel and 40 per cent. copper. For temperatures as high as 1800° F. one wire of 90 per cent. nickel and 10 per cent. chromium, the other wire 98 per cent. nickel and 2 per cent. aluminum, gives very satisfactory results. Either a millivoltmeter or a potentiometer is employed to measure the voltage produced by the thermocouple, the latter method being preferable where the greatest precision is required. In modern instruments provision is made for maintaining the cold junction of the thermocouple at a constant temperature.

The radiation pyrometer is a development of the thermo-electric pyrometer. Instead of placing the thermocouple inside the furnace where the temperature may be so high as to destroy it, it is placed in the back of a tube in front of a mirror. The rays of heat from the furnace enter the tube and strike the mirror, which brings them to a focus on the thermocouple. This instrument has a particular field for temperatures above 4800° F., and results with an error limit within 1 or 2 per cent. are secured.

If accurate results are to be secured from pyrometers, it is very essential that they be standardized at frequent intervals. The greatest future of pyrometry undoubtedly lies along the line of automatic temperature control, and great strides have been made in this country within the past few years in improving methods of heat treatment. Instruments which automatically control the temperature of electric furnaces have already been designed. These instruments maintain temperatures constant within 10° F.

NOTES FROM THE PHYSICAL LABORATORY OF THE UNITED GAS IMPROVEMENT COMPANY.*

EVIDENCE THAT PERSISTENCE OF VISION IS A PHYSICAL CONDUCTION PHENOMENON.

By Herbert E. Ives.

In developing a physical theory to explain persistence of vision and the behavior of the flicker photometer, Ives and Kingsbury [1] have made use of the Fourier conduction equation, thereby assuming that the necessary sluggishness of the visual apparatus is introduced by the transmitting medium, *e.g.*, the optic nerve, which would accordingly have the characteristics of a cable or telephone line of considerable length.

An alternative and perhaps simpler assumption would be that the inertia is a property of the surface at which the reaction due to light takes place, the effective length of the transmitting system being negligibly small, so that the reaction may be considered as being measured at the point of occurrence.

This condition may be expressed by the equation

$$I_0 = c\frac{d\theta}{dt} + b\theta \qquad (1)$$

where I_0 = intensity of stimulus, *i.e.*, rate of reception of radiant energy.

t = time.

c = capacity of surface.

θ = quality (*e.g.*, temperature, potential, concentration, etc.).

b = coefficient of loss of energy, as by radiation or conduction.

If this surface receives radiant energy whose intensity varies in a periodic manner, as represented by the equation

$$I_0 = \frac{I_1}{2} + \frac{I_1}{2}\sin \omega t \quad \left(\begin{matrix}\omega = \text{angular speed} = 2\pi \times \text{frequency} \\ t = \text{time.}\end{matrix}\right) \qquad (2)$$

the resultant reaction is given by the equation

$$\theta = \frac{I_1}{2(b^2 + c^2\omega^2)}(b \sin \omega t - c\omega \cos \omega t) + \frac{I_1}{2b} + \left(\frac{I_1 \omega c}{2(b^2 + c_1\omega^2)} - \frac{I}{2b}\right)e^{-\frac{bt}{c}} \qquad (3)$$

* Communicated by the Chief Physicist.

[1] *Philosophical Magazine*, November, 1914, p. 708, and April, 1916, p. 290.

It is evident that if ω is made large enough a uniform effect is produced after the steady state is reached, proportional to $\frac{I_1}{2}$. This treatment is therefore satisfactory in so far as Talbot's law is concerned.

In order to choose between this treatment and the one involving the idea of conduction, it is necessary to study the speed of disappearance of flicker. An apparently crucial test is furnished by studying the critical speed for two dove-tailed sine-curve stimuli, I_1 and I_2. Introducing these in equation (3), it is found by differentiation that the range of amplitude of the reaction is

$$R = \frac{I_1 - I_2}{\sqrt{b^2 + c^2\omega^2}} \tag{4}$$

and the fraction this is of the mean amplitude is

$$\delta = \left(\frac{I_1 - I_2}{I_1 + I_2}\right)\frac{2b}{\sqrt{b^2 + c^2\omega^2}} \tag{5}$$

If we assume that the condition for disappearance of flicker is the constancy of δ we may solve for the critical speed, obtaining

$$\omega_c = \frac{2b}{c\delta}\sqrt{\left(\frac{I_1 - I_2}{I_1 + I_2}\right)^2 - \left(\frac{\delta}{2}\right)^2} \tag{6}$$

If ω is plotted against $I_1 - I_2$ for small values of δ, it is evident that the result is practically a straight line. Actually, as shown by experiment, the relationship is represented by a pronounced curve, to which fact is largely due the sensibility of the flicker photometer.

The equation similar to (6) which is derived from the conduction theory is

$$\omega_c = \frac{2K\left(\log\frac{2}{\delta} + \log\frac{I_1 - I_2}{I_1 + I_2}\right)^2}{(x \log e)^2} \tag{7}$$

which represents the experimental facts excellently.

Other equations similar to (1) which have been suggested for visual processes and which do not take into account the effect of a transmitting medium appear to fail in the same way.

It thus appears that the damping effect to which persistence of vision is due is located in a conducting medium, which fact must be recognized in any theory of visual response.

THE COLOR TEMPERATURE OF ILLUMINATING GAS FLAMES.

By E. F. Kingsbury.

It is of considerable importance in the photometry of gas flames to know their color temperature, because it determines the efficiency at which incandescent electric lamps must run to match them in color.

While the color temperature of the ordinary illuminating gas flames has been known approximately for a long time, recently the question of its variability with the quality of gas and the flame size arose; so the following data may be of interest. Each flame was matched against a carbon lamp whose efficiency was accurately known at several voltages. Using the data on color temperature given by Hyde and Forsythe in the March Institute Journal, these matching voltages have been evaluated in terms of temperatures:

Color Temperatures of Various Gas Flames.

Source	Lamp voltage (E. T. L. No. 4621)	Color temperature °K.
1. Coal gas, full flame	111.0	2075
2. Coal gas, half turned down	107.5	2035
3. Water gas, full flame	115.4	2118
4. Water gas, half turned down	105.5	2015
5. Water gas, full flame, edge on	111.5	2080
6. Mixed gas, full flame	113.5	2095
7. Coal gas, full flame	113.8	2100
8. Coal gas, candle-shaped flame, height of Hefner	97.0	1940
(Reference points)		
9. Pentane lamp	93.5	1914
10. 4.85 w.p.m.s.c.p. carbon	110.4	2070
11. 3.73 w.p.m.s.c.p. carbon	118.8	2153
12. Hefner	88.0	1875

Nos. 1 to 6 inclusive were using an 8-foot Von Schwarz excavated head lava tip; No. 7 was with an 8-foot Bray Union jet tip, and No. 8 was with a ⅛-inch open tube; Nos. 9 to 12 were taken as references from the paper referred to. The coal gas was 8 to 9 candle-power and 575 B. T. U.; the water gas 27.5 candle-power and 690 B. T. U., and the mixed gas, 25 candle-power and 665 B. T. U.

As is to be expected, the color temperature of a flame is with-

in certain limits dependent upon its shape, size, position, and composition of the gas. It will also vary in different parts of the flame, the values given above being integral over the entire surface. It will be noted the full flames are slightly whiter than the ordinary 4 w. p. h. c. p. carbon standards. The color temperature of 1870° for the mixed gas flame given by Hyde and Forsythe in the paper referred to is considerably lower than any of the above values, which represent extremes in illuminating gas characteristics.

THE UNITED GAS IMPROVEMENT COMPANY,
PHYSICAL LABORATORY,
April 16, 1917.

Boron-Copper. ANON. (*La Chronique Industrielle*, vol. 40, No. 285, p. 2, March 16, 1917.)—Isolated for the first time by Moissan in 1895, and since several years made commercially available by the researches of Dr. Weintraud in the laboratory of the General Electric Company at West Lynn, Mass., boron possesses great affinity for certain substances to the exclusion of others. This property is particularly available in the refinement of copper in which dissolved gases, particularly oxygen, cause blowholes and porosity. In the past the elimination of these impurities has been effected by additions of magnesium or zinc, but these metals formed alloys with copper of inferior conductivity. Boron, however, has no affinity for copper and combines energetically with the oxygen, thus eliminating the gas and its effects.

As produced by the National Alloys Limited of Ilford (Essex), which has developed the product, boron-copper consists of electrolytic copper of the greatest purity. Impregnated with fluoride of boron in the gaseous state, the resulting product is employed as a deoxidizing agent in the production of various metals and alloys. Copper castings of exceptional soundness and electrical conductivity are obtained by the addition of 1 per cent. to 3 per cent. of boron-copper. Radiographic examination, recently introduced in metallurgical technology, shows a marked difference in microstructure between the metal treated with boron and the untreated metal, the boron metal being quite uniform, while the untreated metal, though of good quality, shows marked porosity. Boron-copper is equally applicable to all alloys of which copper is a constituent, from gold to steel, including the intermediate types, such as tin, zinc, nickel, lead, and aluminum. Alloyed with steel in the same manner as nickel, but using half the amount required of the latter, a steel substantially equal in quality to nickel-steel is obtained and at lower cost.

NOTES FROM RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

IMPROVEMENT IN HOT-WIRE ANEMOMETERS.

THE electrical hot-wire anemometer is based on the principle, discovered experimentally in 1909,[1] that a thin uniform wire, kept at constant resistance and temperature by an adjusted continuous electric current, and immersed in a uniform transverse wind, dissipates heat convectively in proportion to the temperature elevation of the wire above that of the passing air, and also in proportion to the square-root of the wind velocity. Experimental measurements of wind velocity employing this principle have been made by Kennelly and Sanborn,[2] by Morris,[3] and by L. V. King.[4] In these measurements the wind-measuring wire forms one branch of a Wheatstone or Kelvin electric bridge, and is kept at constant resistance, which means constant absolute temperature, while the electric power dissipated by the wire is observed. The total wind velocity (including the virtual velocity of free convection at rest) is then pro-

* Communicated by the Director.

[1] "The Convection of Heat from Small Copper Wires," by A. E. Kennelly, C. A. Wright, and J. S. Van Bylevelt, *Trans. A. I. E. E.*, June, 1909, vol. 28, p. 363, part i.

[2] "The Influence of Atmospheric Pressure upon the Forced Thermal Convection from Small Electrically Heated Platinum Wires," by A. E. Kennelly and H. S. Sanborn, *Proc. Am. Phil. Soc.*, April, 1914.

[3] "The Electrical Measurement of Wind Velocity," by J. T. Morris, *The Electrician*, October 4, 1912, pp. 1056–1059.

"Distribution of Wind Velocity About a Circular Rod," by J. T. Morris, *Engineering*, vol. 96, pp. 178–181, August 8, 1913.

[4] "On the Convection of Heat from Small Cylinders in a Stream of Fluid," by Louis Vessot King, *Proc. Royal Society*, vol. 90, May 5, 1914.

"On the Precision Measurement of Air Velocity by Means of the Linear Hot-wire Anemometer," by Louis Vessot King, *Phil. Mag.*, vol. 29, April, 1915.

"The Linear Hot-wire Anemometer and Its Application in Technical Physics," by Louis Vessot King, JOURNAL OF THE FRANKLIN INSTITUTE, January, 1916.

portional to the square of the power per degree Centigrade temperature elevation, or

$$V = \frac{1}{k' p} \left(\frac{P_e}{\theta} \right)^2 \quad \text{cm./sec.} \qquad (1)$$

where p' is the atmospheric pressure (bars)
P_e is the linear dissipation (abwatts/cm.)
θ is the temperature elevation (deg. C.)
k' is a constant depending on the surface condition.

It is evident that if the temperature of the moving air changes during the test the apparent total wind velocity at constant resistance of the test wire will also be changed. If the working temperature of the test wire is kept high, changes in the ambient temperature will have relatively small effects; but if the test wire is operated at, say, 50° C., while the ambient temperature of the air in the wind is at 20° C., a small change in the ambient temperature will affect the deduced wind velocity V materially.

A compact form of Wheatstone bridge $ABCD$, used by Morris, had two arms, AB and CD, of platinum test-wire, and the other two, BC and AD, of Ia-Ia constant-resistance wire. Exposing all four wires to the wind, a Wheatstone bridge served to keep the tungsten wires at such temperature as made their resistances equal to those of the Ia-Ia wires.

Mr. Richard D. Fay, in a thesis towards the S.B. degree at the Massachusetts Institute of Technology this year, shows that the Morris bridge is essentially uncompensated for changes in ambient temperature, and that the observations must be corrected for such changes in order to arrive, by formula (1), at the total wind velocity. This difficulty can be overcome and an automatic compensation arrived at by making all four arms of the bridge of either tungsten or nickel wire. The two arms previously of Ia-Ia wire are now each made of two parallel tungsten wires, so that a bridge $ABCD$ will have one wire from A to B, two from A to D, one from B to C, and two from D to C. The doubled wires are longer than the single wires in a ratio a of, say, about 2.5.

Under these conditions it will be found that if the same wind velocity acts constantly upon all six wires, if the ambient

temperature changes, the bridge balance will be affected in such a manner that when balance is restored the total velocity is again proportional to the square of the power. In other words, the linear dissipated power P_e in (1) keeps automatically in direct relation to the temperature elevation θ when the bridge is kept balanced. A given set of six wires in constant surface condition thus requires a definite and constant temperature elevation for resistance balance under all ambient temperatures.

The advantage of this plan is not only that the observed wind velocities require no correction for ambient temperature, but also that low temperature elevations may be used. The test-wire device, in the most satisfactory form tried, had six fine nickel wires (diameter 0.155 mm.) mounted insulated in a sort of cobweb across a light brass circular frame 15 cm. in diameter. This frame was fastened to a handle, with the bridge wires leading over it to the battery, controlling rheostat, ammeter, and balance galvanometer. The nickel wire used had inferred absolute zero resistivity at $-233.6°$ C., and the length ratio $a = 2.083$. The temperature elevation θ was only about 15° C., and the wires did not become dangerously overheated if the bridge was balanced at a wind velocity of 18 metres per second (40 miles per hour) and then laid on table or removed from the wind. The wind velocities are proportional to the fourth powers of the total current supplied to the bridge for balance, this current varying from 0.74 ampère in still air to 2.18 ampères in air moving at 17.5 m./sec. (39 miles per hour). Calibration in a wind tunnel indicated a good straight-line law, on logarithm paper, between currents and actual wind velocities. This new automatic compensation principle promises to be useful in anemometry.

Exposure and Size of Plate in Wide-angle Photographs. ANON. (*British Journal of Photography*, vol. lxiv, No. 2972, p. 202, April 20, 1917.)—In the general case of wide-angle views, it is well known that an exposure just sufficient for the centre of the plate will be altogether inadequate at the corners. The falling off of the illumination at the corners is, of course, influenced very largely by the cutting-off effect of the lens mount when the aperture is over a certain size, therefore for high-speed work at large aperture we need a lens giving a fairly wide angle of full illumination. The mount nearly

always cuts off some light, but by stopping down the aperture we can increase the angle of full illumination very materially and so avoid any interference by the mount up to very large angles. In that case the uncertain effect of the mount is eliminated, the illumination of the plate varies according to a definite rule, and it becomes possible to calculate the difference in exposure required, as the distance from the centre of the plate increases.

According to the rule given by Doctor Zschakke, the light entering the emulsion at any point on the plate is proportional to the fourth power of the cosine of the angle of obliquity of the light pencil, so that if this angle is θ, the light everywhere is proportional to $\cos^4$. We can then use this rule to determine the relative exposures at the corners and at the centre of the plate when a sufficiently small stop is used to make the angle of full illumination cover the whole plate. Taking an angle of 90 degrees, for example, with which the diagonal of the plate must be twice the focal length, the corners require four times the exposure necessary at the centre. With an angle of 105 degrees the corners require seven times the exposure at the center. With extreme wide angles this must always be the difficulty. Hence the origin of various patent lenses with revolving star stops, etc., designed to cut down the light in the centre of the plate.

Use of a Mirror in Portraiture. A. F. CATHARINE. (*British Journal of Photography*, vol. lxiv, No. 2973, p. 217, April 27, 1917.) —There is nothing original or new in the idea of making a photograph of a reflection in a mirror, but it is a useful expedient that does not seem to have been often employed. When the space available is too small to permit the use of a long focus lens, by introducing a mirror a viewpoint in effect is obtained beyond the wall of the room. The camera and sitter may be placed close together, with the mirror facing some point between them. The exterior focal distance is then the sum of the distances of the mirror from camera and sitter.

The negative naturally is a reversed one, and is only suitable for printing direct in single-transfer carbon, unless films are used which can be printed from either side. If the negative is for enlargement, the reversal is of no consequence, as it need be merely turned around in the carrier. By employing a lens with a slight amount of spherical aberration a most pleasing and even softness of definition is secured. Probably this is due to the fusion of the main and secondary images respectively reflected from the back and front of the glass. It gives to the image a certain luminosity of a somewhat similar character to a direct print from a negative made with a soft-focus lens. The texture of the image is not destroyed or even impaired, but there is a slight blurring outward from the *high-lights*. This gives an entirely different effect from that obtained in a direct bromide enlargement with layers of tulle on the projection lens, which produce an outward blurring from the *shadows*.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, May 16, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 16, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 5.

The Chairman announced that the business of the meeting would be the annual presentation of the Franklin Medal, the Institute's highest award, in recognition of distinguished scientific and technical achievements, and called upon Dr. Harry F. Keller, who gave an account of the work of Dr. Hendrik Antoon Lorentz, of the University of Leiden, recently recommended by the Institute's Committee on Science and the Arts for the Franklin Medal in recognition of "His researches which have so largely contributed to laying on a new foundation our knowledge of the nature of light and in developing our ideas concerning the ultimate constitution of matter."

Doctor Keller then presented His Excellency, Chevalier W. L. F. C. van Rappard, Ambassador of the Royal Netherlands Government to the United States, who received the medal for Doctor Lorentz, and conveyed the thanks of his Government and of the recipient for the honor conferred upon him.

Doctor Keller then introduced Admiral David Watson Taylor, U. S. Navy, who had also been recommended for the award of the Franklin Medal in recognition of "His fundamental contributions to the theory of ship resistance and screw propulsion, and of his signal success in the application of correct theory to the practical design of varied types of war vessels in the United States Navy."

The Chairman presented the medal to Admiral Taylor, who expressed his thanks for the honor conferred upon him and then read his paper on "The Science of Naval Architecture." He gave an outline of the progress in ship design and shipbuilding, and pointed out the dependence of naval architecture on the various other sciences, including mathematics, astronomy, chemistry, physics, physiology, medicine, and hygiene. Reference was made to the increase in the size of ships, their strength and stability, and consideration was also given to the question of resistance and the results of experiments conducted in the model basin.

Adjourned.

R. B. OWENS,
Secretary.

(A full account of the meeting will appear in the next issue.)

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, May 2, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 2, 1917.

MR. WM. CHATTIN WETHERILL *in the Chair.*

The following reports were presented for first reading:

No. 2671.—Stellite. Advisory.

No. 2685.—Beach Reclamation Works. Advisory.

The following report was presented for reconsideration and adopted:

No. 2682.—Hooven Automatic Typewriter. Thomas A. McCall and John H. Pillings recommended to the City of Philadelphia for John Scott Legacy Medals and Premiums for their inventions embodied in this machine. The Edward Longstreth Medal of Merit awarded to the Hooven, Owens, Rentschler Company for the development of means of manufacturing this typewriter.

The following reports were presented for final action:

No. 2683.—Yeomans Method of Machine Construction. Lucien I. Yeomans recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

No. 2687.—Portable Brinell Hardness Tester. Report referred back to Subcommittee for further consideration.

R. B. OWENS,
Secretary.

SECTIONS.

Sections of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 26, 1917, at eight o'clock, with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were read and approved.

George E. Hale, Ph. D., Sc. D., LL. D., F. R S., Director of the Mount Wilson Solar Observatory, Pasadena, Calif., delivered an illustrated lecture on "Whirlwinds and Sunspots." A description was given of whirling storms in the earth's atmosphere (cyclones, tornadoes, and waterspouts), and of analogous solar storms, as shown by the study of the sun's upper atmosphere by means of the spectroheliograph, and by the spectrographic study of sun-spots. The magnetic phenomena associated with solar vortices and their bearing on the nature of sun-spots were also discussed.

The paper was discussed, a vote of thanks was extended to Doctor Hale, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, May 9, 1917.*)

RESIDENT.

MR. EBER W. FINKBINER, Representative, E. F. Houghton & Co., and for mail, 5219 Columbia Avenue, Philadelphia, Pa.

DR. ANNABELLA E. RICHARDS, Demonstrator of Chemistry, Women's Medical College of Philadelphia, and for mail, Merion, Pa.

ASSOCIATE.

MR. GORDON MEADE ATHEROLT, Engineer, Atlantic Refining Company, and for mail, 1723 North Twenty-eighth Street, Philadelphia, Pa.

MR. ALBERT DE MACEDO, Mechanical Engineer, Midvale Steel Company, and for mail, 3925 Poplar Street, Philadelphia, Pa.

MR. BERNARD L. DOUREDOURE, Student, 103 Walnut Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. ANDREW ALLAN, JR. Harrison, N. J.

MR. C. W. BARWIS, care of Pennsylvania Railroad Company, Wilmington, Del.

MR. M. D. BURKE, R. F. D. No. 8, Ashland, Ohio.

MR. R. G. COOLBAUGH, care of Camden Forge Company, Camden, N. J.

MR. JOHN P. EATON, 1373 Narragansett Street, Philadelphia, Pa.

MR. EDWIN ELLIOT, 250 West Johnson Street, Germantown, Philadelphia, Pa.

MR. JAMES GAYLEY, 555 Park Avenue, New York City, N. Y.

MR. J. ROGERS HOLCOMB, Walnut Hill, New Castle, Del.

MR. TINIUS OLSEN, The Gladstone, Eleventh and Pine Streets, Philadelphia, Pa.

MR. LAWRENCE T. PAUL, 118 Mill Street, Newport, R. I.

MR. A. B. STITZER, care of Republic Railway and Light Company, 60 Broadway, New York City, N. Y.

MR. HARRISON D. STRATTON, 1007 Irwin Avenue, Pittsburgh, Pa.

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BOOK NOTICES.

LAWS OF PHYSICAL SCIENCE: A REFERENCE BOOK, by Edwin F. Northrup, Ph.D. Philadelphia, J. B. Lippincott Company, 1917. 210 pages, 12mo. Price, $2.

The purpose of this book may be inferred from the following paragraph in the preface: "The *data* of physical science are readily accessible in several published tables of physical constants. The *mathematics* used in physical science has been summarized, classified, and formulated for ready reference in many published books. The author is not aware, however, of any handbook or reference work which contains a full list of the *general propositions* or *laws of science*."

The reviewer thought to test the volume and so wrote down a score of topics which might come under the general purpose of the book, and the book stood the test well. Ohm's law for electric currents happens to have been omitted from the index, but is found in the text. Poisson's ratio, the Stark (Lo Surdo) effect, and series of spectral lines were not found, but in strictness these are not "general propositions or laws of science," and the author must draw a line somewhere.

In all, about six hundred topics are treated, and well treated. References are given to more extended discussions of each topic, and a bibliography tells us just what edition of a book is referred to. In this connection one wonders sometimes why so ancient an edition is cited. It is interesting to

note that all the books referred to are written in either French or English, with the exception of just one in the language of our enemy.

The book before us has so high a value and is so likely to be revised that the author will pardon a suggestion or two for the second edition. Would it not add to the value to refer in each case to the original paper as well as to subsequent treatments? Further, the index should be made more ample, since it is by thumbing it that the approach to the book will be made. Some topics should be otherwise located. Curie's Law of Magnetic Susceptibility should be classified with Magnetism and not in its present position under Heat and Physical Chemistry.

The reviewer finds he has spent some words in apparent disparagement. Did he not regard the book as useful and valuable he would not have wasted time in making suggestions. His opinion is that Doctor Northrup has done a needed piece of work very well indeed. He has given the physicist a good additional tool, and every one having to do with physics, closely or remotely, should keep this book near to his elbow.

GEORGE F. STRADLING.

HANDBOOK OF ENGINEERING MATHEMATICS, by Walter E. Wynne, B.E., and William Sparagen. New York, D. Van Nostrand Company, 1916. 200 pages, 4 x 6½ inches, 113 illustrations, with tables. Price, $2 net.

A compendium of information bearing upon the subjects with which the engineer has to deal in professional practice is a well-recognized necessity, and in recent years the number of handbooks available for this purpose has considerably increased. These books, containing a large collection of engineering data, include a brief section on pure mathematics, and many users doubtless wish that this feature were presented in greater detail. The volume, in keeping with its title, covers this ground much more thoroughly and will appeal to those who require a greater amount of mathematical data than is contained in the customary handbook.

While mainly devoted to mathematics, the work contains brief chapters on theoretical mechanics, mechanics of materials, hydraulics, and electricity. It is stated in the introduction that it is primarily intended for students in engineering as a convenient reminder of things easily forgotten. Practising engineers are probably in greater need of a convenient reminder than students who have the facilities of the college library. The chapters on applications are scarcely full enough to meet the needs of the former class of users. Besides, the inclusion of this material takes up space that might better be devoted to a greater number of mathematical theorems. For instance, the chapters in algebra and analytic geometry are quite brief and might be considerably amplified. The chapters on the calculus and differential equations, on the other hand, embrace a very satisfactory outline of the subjects and cover the ground in considerable detail. The purpose of its authors perhaps justifies the plan adopted, but to satisfy the users who have had the opportunity of examining other books on engineering mathematics, the work might well be double its present volume. A bibliography might also be included. Nevertheless it contains much valuable information in just that readily available and compact form that will save both time and energy.

LUCIEN E. PICOLET.

THE "MECHANICAL WORLD" POCKET DIARY AND YEAR BOOK FOR 1917. Baltimore, The Norman, Remington Company, 30th year of publication. 332 pages, illustrated, 4 x 6 inches, cloth. Price postpaid, 40 cents.

Thirty years ago, when the Pocket Dairy was first issued, there was little literature of that kind available in English. There are now several handbooks covering each of the various departments of engineering. Despite the advent of these, the Diary, in the field of mechanical engineering, still finds a wide sphere of usefulness; perhaps because of its low cost, but more probably because of the evident discrimination shown in compiling the subject-matter. Exclusive of index and advertisements, there are only 265 pages of printed matter, but in this relatively small space a very large amount of data of the kind required by the machine designer has been condensed. The book has been brought up to date by the addition of a section on the heat treatment of steel and a number of new tables. British standards predominate.

LUCIEN E. PICOLET.

PUBLICATIONS RECEIVED.

Explosives, by Arthur Marshall, A. C. G. I., F. I. C., F. C. S., Chief Inspector, Indian Ordnance Department. Second edition. Vol. 1, History and Manufacture. 407 pages, illustrations, quarto. Philadelphia, P. Blakiston's Son & Company, 1917. Price, for two volumes, $16.

The Method of Enzyme Action, by James Beatty, M. A., M. D., D. P. H., with introduction by Prof. E. H. Starling, M. D., Sc. D., F. R. S. 143 pages, 8vo. Philadelphia, P. Blakiston's Son & Company, 1917. Price, $1.75.

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CURRENT TOPICS.

Expenditure of Ammunition. ANON. (*The Field Artillery Journal,* vol. vii, No. 1, p. 31, January-March, 1917.)—That the expenditure of field artillery ammunition in the present war has been enormous, and beyond any conception based upon previous experience, is well known, but, like many other matters of importance, exact data have not generally been available. The following, taken from General Sixt von Arnim's report concerning the battle of the Somme, July, 1916, are extremely interesting, in that they give the maximum expended in any one day of 24 hours, and the average daily expenditure during the entire month of July, 1916:

1. Maximum artillery ammunition expended in any one day of 24 hours:

77-mm. field gun	322	rounds per gun
105-mm. field howitzer	479	rounds per gun
150-mm. howitzer	233	rounds per gun
105-mm. gun	321	rounds per gun
210-mm. mortar	116	rounds per gun

2. Daily average (24 hours) during July, 1916:

77-mm. field gun	145	rounds per gun
105-mm. field howitzer	170	rounds per gun
150-mm. howitzer	119	rounds per gun
105-mm. gun	118	rounds per gun
210-mm. mortar	51	rounds per gun

3. One field battery (howitzers) expended in one day 3500 gas shells.

The actual number of guns in action is not known. The best information gives a probable number of one field gun, exclusive of heavy types, for every 20 yards of front. The approximate frontage of the Somme battle was 40 miles, so that the number of field guns engaged numbered in the vicinity of 3500. Each gun fired 145 projectiles per day, or a total of 4495 for the month, and the total fired becomes 15,732,500. The German 77-mm. projectile weighs seven kilogrammes, or 15.4 pounds, so that the total weight fired was 242,280,500 pounds, or 121,140.25 tons. The computed weight of the heavy artillery ammunition would probably more than double this amount.

Such figures only serve to demonstrate the vastness of the conflict in Europe, and to point out to us the enormous difficulties of ammunition supply, both in manufacture and carriage to the guns. And we must remember that in the battle of the Somme the Germans were on the defensive and lost ground, so that the above expenditure

does not even represent a successful defence. The figures also point out the difficulties in the way of a rapid advance after a line of fortifications has been pierced. First the guns must be moved forward, in itself a slow and difficult task, over the broken and shell-torn ground; then, over the same ground, roads must be constructed, or the light field railway must be laid and a new ammunition supply established. The time necessary for these operations is much longer than that necessary for the defence to establish a new trench line, and the attacking infantry in modern war dare not go beyond the support of its artillery.

The Electrolytic Pickling of Steel. M. DEK. THOMPSON and O. L. MAHLMAN. (*Proceedings of the American Electrochemical Society*, May 2–5, 1917.)—All iron and steel objects which in the process of manufacture have been heated in the air are covered with "fire scale," which is an oxide of iron. This has to be removed before the surface can be plated or galvanized. The usual practice has been to immerse the objects in some acid until the scale is removed by the hydrogen formed by the action of the acid on the iron beneath the scale, which it reaches through the cracks in the scale. The action which would be expected if a sheet of iron covered with scale were used as a cathode in an acid solution is a reduction from a higher to a lower oxide. This oxide would be dissolved by the acid. There would also probably be a certain amount of chemical action between the iron under the scale and the acid, as in the purely chemical treatment. It is this action which the electrochemical process attempts to avoid as much as possible.

The method of comparing the two operations consisted in treating two similar mild steel plates by the two methods until their appearance showed that the pickling was completed. The scale was produced by heating for two to eight minutes pairs of plates in a muffle furnace and cooling them in air. One of these was then treated by the chemical method, the other by the electrolytic method. In two experiments the saving effected, in acid and amount of iron removed, for every 2000 pounds of iron, including the cost of power, was about $70, and in a third about $50. While these results differ considerably and are probably due to accidental differences in the quality of the scale, they point to important economies that may result from the adoption of the electrolytic method.

Manufacture of Rifles for the United States Forces. S. TRASK. (*Arms and The Man*, vol. lxii, No. 5, p. 83, April 28, 1917.)—When war was declared and it became certain that the national army would assume, numerically, great proportions, the ordnance experts of the army immediately realized that the output of Springfield rifles from the Springfield and Frankford arsenals would by no means meet the increased demand, or even keep pace with the recruiting. To meet just such an emergency, efforts have been made in Congress to secure

the necessary appropriation for increasing the output of the standard arm. It was realized, however, that much time would be consumed in the manufacture of the special tools required and that there would still be a shortage of rifles. It was therefore the consensus of opinion that an emergency arm should be selected.

At the present time thousands of the British Enfield, the Russian Nagant and the French Lebel rifles are being turned out every day in the United States, together with some less modern types. That source of supply being immediately available, it has been decided to select one of these, chambered to take service ammunition, as the emergency rifle of the United States. Because a greater number of factories are equipped to manufacture the British Enfield and the output is greater than any other, it being possible within six months to produce between 6000 and 11,000 a day, this arm will probably be adopted. Two patterns of the Enfield are now in use in the British Army. The newer so-called "Model 1914" will probably be the one chosen if the United States definitely decides to manufacture this arm. The rifle is considerably heavier than the Springfield, weighing 9 pounds 5 ounces, the barrel being 26 inches long, against the Springfield weighing 8 pounds 12 ounces, with a 24-inch barrel. In the British pattern—the kind now being manufactured in the United States—the calibre is 0.303 inch, and the barrel is rifled with five grooves, with a pitch of one turn in 10 inches. The Springfield has four grooves with the same pitch. The rifle is loaded by a charger holding five rounds. No cut-off is provided. The bottom of the magazine comes flush with the stock, and is removable for cleaning and repair.

Detecting the Presence of Submarines by Means of Aircraft. H. WOODHOUSE. (*Flying*, vol. vi, No. 4, p. 271, May, 1917.)—The usual evidence of a submarine's presence is the wake of the periscope. This wake cannot easily be seen from ships, but can always be clearly seen from aeroplanes. The aviator is not troubled by the refraction of light which interferes with vision from a ship, and at a height of 1000 to 1500 feet, with a range of vision of many miles, the whitish wake of the periscope is clearly visible against the dark surface of the waters, even in cases where the sea is fairly rough and white-caps are showing. In clear weather an aviator at a height of 1000 to 1500 feet can see a submarine under water when the water is clear, even when the submarine is at a depth of 100 feet; in less clear water the submarine can be seen at a depth of 20 to 30 feet.

Present-day submarines are so large that they not only can be detected through the contrast which they make against their surroundings in the water, but also through the foamy wake at the stern, which is clearly visible by contrast. Exhaustive experiments have been made in painting submarines so as to make them less visible when they are under water. They can be made less visible by painting them in colors that blend well with the color of the water, but

it is hardly possible to so paint the large fleet of submarines and ocean-going super-submarines, which are used for long cruises, in such a way as to blend with the water and conditions existing in different places in which they are cruising. The smaller coastal type submarine, which is used entirely for coast defence and does not have to make long cruises, can be painted more effectively to blend with the color of the water in which it operates. Nothing, however, can be done to eliminate the foamy wake of the periscope, and if the periscope were eliminated the submarine would have to come close to the surface, where it would make a better target for the aviator.

Many submarines escape attack because aviators cannot distinguish hostile from friendly submarines and make no attempt to destroy them when in doubt as to their identity. Marking submarines does not afford a solution, because the enemy can adopt the markings and carry on its work of destruction under disguise. Hundreds of kite balloons have been used as lookouts for submarines in the great war. These balloons are sent up from barges or kite balloon ships, and are sent up to a height of 1000 to 2000 feet, where they stay throughout the day, the observers scanning the surface of the water, looking out for submarines. When they discover a submarine or doubtful ship, they summon aeroplanes, destroyers, or submarine chasers by wireless.

The Split-phase Motor. F. S. DELLENBAUGH, JR. (*The Electric Journal*, vol, xiv, No. 5, p. 198, May, 1917.)—It is difficult to realize, now that single-phase motors are manufactured by the hundred thousand, that not many years ago they were considered an engineering curiosity and even after coming into practical use were uncertain in action. To understand why this type of motor is called "split-phase" and why a switch is necessary, its early development must be understood. To Tesla belongs the credit of conceiving the ideas leading to the experiments which resulted in the first successful induction motor. The first alternating-current motor was a two-phase machine, which was built after he discovered that the proper arrangements of windings upon the starter for each of the two phases resulted in a whirling flux. Any conductors in this whirling field are dragged around very much like leaves in a whirlwind. This principle of a revolving magnetic field is the basis for the operation of all induction motors. It is necessary to have two sources of magnetizing current having a difference of phase in order to produce this rotating field. Therefore it was with considerable surprise that Tesla accidentally discovered that his two-phase motor would continue to run if one phase were disconnected after it has reached full speed. In other words, he accidentally obtained the first single-phase motor.

Although it was not clear at the time just why the motor ran, later it was discovered that the magnetic reaction of the rotating parts furnished the second magnetizing current which produced the rotating field. This second component of the magnetizing field is

absent when the motor is not moving; an oscillating instead of a rotating effect is then the only result. Evidently this gives zero starting torque, and therefore the next problem was the development of some means of starting this newly-discovered single-phase motor. The most obvious method of starting the machine was to employ some external device which would give two-phase characteristics to a single-phase power circuit. This actually was done by means of a device called a "phase splitter," consisting of two independent circuits connected to the same single-phase line. One of these circuits contained a condenser, and hence had a leading power-factor, while the other included an inductance coil and had a lagging power-factor. When connected to the two windings of a two-phase induction motor, these two circuits gave approximately the same effect as a two-phase current, and would start the machine with somewhat reduced torque. After the motor was up to speed, one motor winding was disconnected and the phase-splitting device was cut out of the circuit.

This system worked satisfactorily, but was never tried out on a large scale commercially, because the phase-splitter was large and expensive, required hand operation, and did not give very large starting torque. The installation of the phase-splitting device in the motor itself was the next step. Engineering development finally produced the present design, in which two windings are still employed with the same mechanical relations to each other that are used in the two-phase motors, but having quite different electrical characteristics. The one winding has a low resistance and a high reactance, while the other has a high resistance and a low reactance. The result is that the power-factor is much closer to unity in one winding than in the other, and the phase displacement is sufficient to give the required whirling magnetic effect, resulting in a starting torque. The high-resistance winding, called the starting winding, if allowed to remain in the circuit, will generate enough heat to destroy the insulation. This heat is the direct result of the high resistance, but if the resistance is lowered the starting torque is proportionally decreased, and at best is only equal to full-load torque. The necessity for removing the starting winding from the circuit as soon as possible is inherently unavoidable in the design of this type of motor. Since the point at which this winding should be disconnected corresponds to a definite point on the speed-torque curve, the obvious way of producing the desired effect is by a centrifugally operated switch. This is the scheme that was adopted, and it has been developed to a very high state of perfection.

Canadian Asphaltic Sand. ANON. (*Scientific American*, vol. cxvi, No. 13, p. 326, March 31, 1917.)—Since the first explorer descended the Athabaska River, upwards of 150 years ago, the existence in the northern part of the Province of Alberta of deposits of asphaltic sand has been recognized. This material consists of approximately 15 per cent. of high-grade bitumen and 85 per cent. of

silicious sand. That the deposits were of large extent was evident, but until recently little was definitely known regarding their true economic importance. For many years the remote geographical position of the deposits and the lack of transportation facilities effectually prohibited any attempt at actual development. With new railroads serving this district nearly completed, however, the difficulty of transportation will have been removed. The important outstanding features presented by these deposits are: (1) They represent the largest known deposits of solid asphaltic material; (2) the deposits are as yet totally undeveloped; (3) at the present time every ton of asphalt used in Canada is imported from foreign countries. The areal extent of the deposits is probably not less than one thousand square miles, and the average thickness is upwards of 100 feet. When adequate markets and transportation facilities become available there seems reason to believe important developments may be expected.

Recently the Mines Branch of the Canadian Department of Mines has undertaken an investigation not only of the deposits themselves, but also of methods best adapted to the commercial treatment of the crude bituminous sand. The results of this work suggest the use of the bituminous sand in a more or less crude form in the surfacing of streets and highways; to separate the asphalt or bitumen from the crude material in order to derive a more or less pure product; or to destructively distil the crude bituminous sand for the purpose of obtaining crude petroleum therefrom. Considering the absence of developed petroleum fields in Canada, such distillation could be undertaken under exceptionally favorable conditions. A study of possible separation and distillation methods is being made at the Mellon Institute of Industrial Research in Pittsburgh. Though details are not yet available, a process for economically effecting the separation has been developed. It is of interest to note that practically the entire area of bituminous sand is under government reserve. There is reason to believe, however, that within a reasonable time this reserve will be removed and provision made whereby private individuals or companies may acquire areas for development.

Artificial Fertilizers. E. J. RUSSELL. (*Journal of the Society of Chemical Industry*, vol. xxxvi, No. 5, p. 250, March 15, 1917.)—Artificial fertilizers are simple salts which are added to the soil to help in the nutrition of plants; they are called "artificial" because they have usually undergone some manufacturing process. They are of three classes: Nitrogen compounds, phosphates, and potassium compounds. It is also useful to add a fourth—organic matter. Almost anything containing these constituents will serve, provided that the substance is not toxic to the plant and that it is capable of going into solution in the soil water directly or as the result of decomposition in the soil, so that it can enter the plant roots. In practice, however, a third condition

is essential: the price must be sufficiently low, and this rules out so many substances that the actual list is short. Grouped under the four classes named, these are: *Nitrogenous.*—Nitrate of soda, sulphate of ammonia, calcium cyanimide, and calcium nitrate. *Phosphatic.*—Superphosphate, basic slag, and bone manures. *Potassic.*—The Stassfurt salts. *Organic.*—Excretions from animals fed on imported feeding stuffs, guano, fish and meat meals, and other manufacturing residues.

These four classes have very different properties, and they are in no sense interchangeable. In laboratory experiments, sand cultures, etc., all the three first-named constituents are necessary for plant growth, but in field practice the soil supplies something, so that artificial fertilizers are needed to make up deficits or to increase production. The only way of finding out what is needed is by actual trial: the hope once entertained that soil analysis would give a short and easy indication of the deficit has not been realized. Moreover, each of these different classes, besides contributing to the general nutrition of the plant, has certain specific effects which can be discovered only by trial.

The fertilizers are mainly simple salts (in other words, electrolytes), and the soil owes most of its important properties to its colloidal constituents. Electrolytes profoundly change some of the properties of colloids, and the effects cannot always be predicted; usually they have to be discovered by experiment. Further, some fertilizers undergo remarkable changes in soil. Nitrate of soda, for example, changes to carbonate of soda, which, as an alkali, has a strong deflocculating action in the clay, thereby greatly modifying the texture of the soil. Sulphate of ammonia gives rise under certain conditions to an acid which changes the reaction of the soil, and a change in reaction of the medium may profoundly affect the growth of organisms and of plants. In dealing with artificial fertilizers, therefore, it is necessary to take into account not only their effect on the plant and their price, but also the changes that they are likely to undergo in the soil and the effects the products will have on the soil and on the plant. These are so complex that they can usually be determined only by direct trial.

Portable Track for French Strategic Railways. ANON. (*The Iron Trade Review*, vol. lx, No. 12, p. 669, March 22, 1917.)—The abnormal traffic of heavy motor trucks over French roads in proximity to the fighting line for more than two years has rendered them almost impassable in many places. In addition to this destructive effect, the roads, like the battlefields, have been furrowed and plowd by bursting shells until all semblance to highway or even lane is blotched out for miles. The problem of transporting the heavy supplies of ammunition, food, and clothing over the shell-torn fields to the points of action has been

greatly simplified by the use of portable track. France is approximately as large as the states of Montana and Ohio combined; the part of the country confined to actual warfare is perhaps one-tenth of this area, yet within that small section there is a network of more than 2500 miles of this narrow-gauge track.

The track is made in convenient lengths—1¼, 2½, and 5 metres—which may be readily connected to curved sections, turntables, and numerous types of switches and cross-overs. The three lengths have three, five, and eight ties, respectively. The gauge is 60 centimetres. The rails, which are rolled to a special size designated by the French Government, weigh 20 pounds per yard. The general appearance of the rail section resembles the standard A. S. C. E. section 16. The ties weigh about 20 pounds each, and withstand a bending stress of more than 4500 pounds. They are pressed hot from 3/16-inch sheet stock into a dished form, measuring 6 × 44 inches, with a ¾-inch rim. The appearance of the sections and the ease with which they may be laid remind one of the very neat toy track and train assortment now in vogue. But this track is built to withstand severe service; it is laid by experienced track layers and carries carload after carload of heavy shells and other supplies. The trains are operated by double-ended Baldwin locomotives. A large percentage of this portable track is made at the plant of the Lakewood Engineering Company, Lakewood, Ohio. At the present time the Lakewood Company is producing from three to four miles of track a day, requiring 80 to 100 tons of rails and 75 tons of tie stock. The contracts completed and active involve more than 8000 tons of this portable track.

Gelatinobromide Ferrotype Photographic Plates. ANON. (*Revue Scientifique*, vol. 55, No. 5, p. 151, February 24–March 3, 1917.)—The collodion photographic negative possesses the peculiar property of appearing as a positive when viewed by reflected light with the plate backed by a black surface. The best-known application of this positive process is embodied in the so-called "tintypes" in vogue some years ago. These tintypes were produced by supporting the sensitized collodion film upon a thin sheet-iron plate coated with black japan varnish. The black surface showing through the transparent parts of the film produces the shadows, while the light-colored but opaque silver particles form the high lights.

The inconveniences of the wet collodion process are well known, and, although dry collodion plates of satisfactory keeping quality have been made, adequate sensitiveness to meet modern requirements has not been secured. The first gelatin ferrotype plates failed to give a sufficiently light-colored deposit for the proper rendering of the high lights, and bleaching with bichloride of mercury was employed with a considerable degree

of success. The lack of permanency of the bichloride bleach, however, proved a serious obstacle to this expedient. By means of special emulsions, Messrs. Lumière have succeeded in producing gelatine ferrotype plates of sufficient speed that yield images comparable in brilliancy to collodion plates and require no other treatment than developing and fixing. It has also been found possible to simplify manipulation by combining the developing and fixing bath. It is suggested that such plates may prove of value in radiographic field operations.

The Corrosion of Cast Iron and its Bearing on the Electrolytic Theory of Corrosion. E. A. RICHARDSON and L. T. RICHARDSON. (*Proceedings of the American Electrochemical Society*, May 2–5, 1917.)—The field of cast iron as regards its usefulness as a rust-resisting metal has been much neglected, and to-day remains almost unexplored. This, no doubt, is due in part to the fact that only in the last few years has the resistance of irons to corrosion been considered one of their important properties. The efforts to improve materials for structural and other purposes have been directed toward the production of a material having superior physical properties, such as tensile strength with a great reliability. This is the reason that cast iron, once extensively used for structural purposes, has been replaced by steel. However, for many other purposes cast iron is still used in enormous quantities in places exposed to corroding influences. Many instances are known where cast-iron objects have lasted many years, even centuries, and have remained in good condition when exposed to corrosive influences, and that when used underground cast iron is usually superior to other kinds of iron.

According to the electrolytic theory of corrosion, cast iron, being less pure and more heterogeneous than steel or pure iron, should rust faster than either of these. Three pieces of these materials were exposed to rusting influences for seven months, then cleaned and weighed. Pure iron corroded least, cast iron 25 per cent. more, and steel 100 per cent. more. The electrolytic theory of corrosion does not explain these results. While it may be true that the initial rusting is largely electrolytic in character, other factors, such as the adherence of the rust and protection given thereby to the metal, come into operation and outweigh any electrolytic corrosion.

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